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ARCHIVES OF SURGERY

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COPPER SULFATE METHOD FOR RAPID ESTIMATION OF WHOLE BLOOD REQUIREMENTS

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ST LOUIS

THIS report is based on a study of severely injured patients admitted to a large general hospital overseas. Of these, 166 had orthopedic injuries of severe degree, 98 others were patients in wards for general surgery. Hemoglobin, hematocrit and plasma protein values were measured before and after surgical treatment, which included particularly the use of large transfusions of whole blood and plasma. The observations indicate that (a) a simple method for measuring hemoconcentration and hemodilution by the copper sulfate specific gravity technic is of great clinical value, (b) large amounts of whole blood are needed in the treatment of the severely injured, (c) several interesting correlations exist between hematocrit values and changes in plasma protein in these cases.

MATERIAL STUDIED

One hundred and sixty-six patients with severe orthopedic injuries were studied carefully, and for 91 of these detailed records of all fluids and blood transfusions were recorded. Of these, 45 had bad fractures of femur, tibia and/or pelvis, 30 also had injuries of the upper extremity, 6 had fractures through the knee joint, all had some, and the majority had extensive, soft tissue wounds with infection, 4 had penetrating wounds of the chest and 1 had had a nephrectomy and an adrenalectomy on the right side.

Opinions expressed herein are those of the author only, and do not represent official views of the Medical Department of the United States Army.

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Members of the Surgical Service of the 21st General Hospital rendered valuable assistance in the preparation of this paper. Captain Orens helped in compiling some of the data.

There were also 98 patients on the general surgical wards with soft tissue wounds of the extremity, the abdomen or the chest that required more blood or plasma than the remainder of the patients on general surgical wards. These were selected from a total of 768

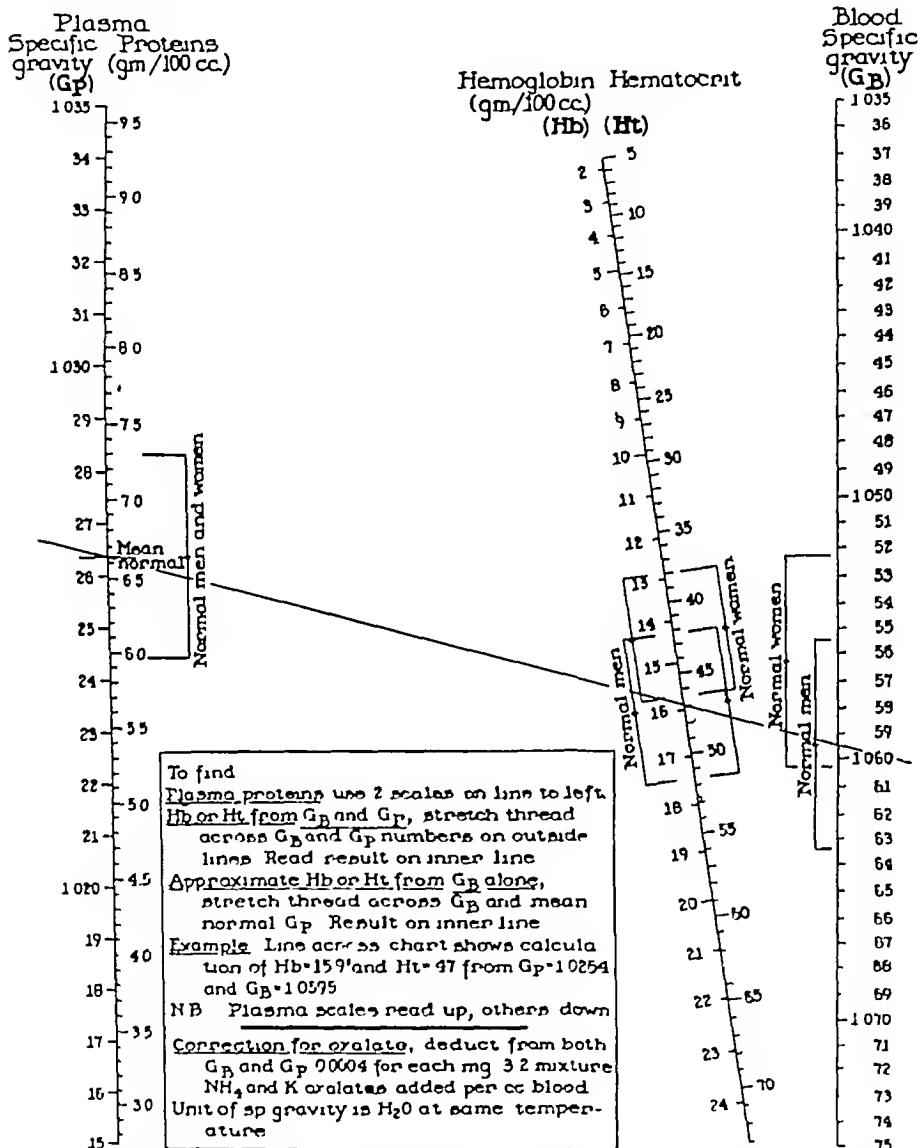


Chart 1—Line chart for calculating plasma proteins, hemoglobin and hematocrit values from gravities of plasma and of blood (from Phillips, Van Slyke, Dole, Emerson, Hamilton and Archibald¹)

patients on the general surgical service for whom copper sulfate determinations of hematocrit values, total proteins and hemoglobin were made during a period in the Italian campaign

Most of the patients had received emergency care and debridement at field or evacuation hospitals, a few, during the Anzio and Cassino offensives, were received directly from battalion aid stations within four to eight hours after injury. In general, however, the periods

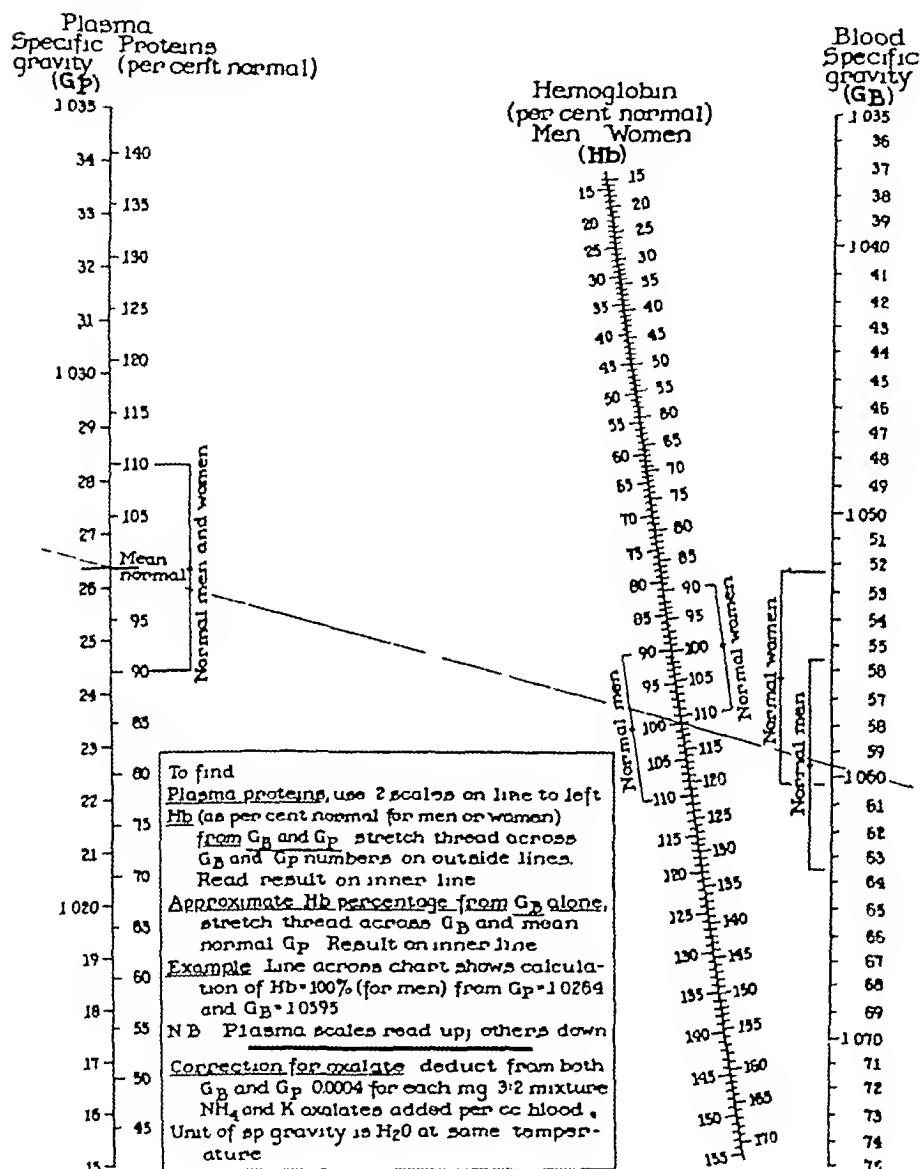


Chart 2.—Line chart for calculating percentages of normal plasma proteins and hemoglobin from gravities of plasma and of blood (from Phillips, Van Slyke, Dole, Emerson, Hamilton and Archibald¹)

elapsing between injury and admission varied from one to sixty-one days, 27 per cent of the patients were received within the first four days and 65 per cent within ten days of injury.

METHODS

The use of solutions of copper sulfate of varying but known specific gravities into which a drop of freshly drawn or oxalated whole blood is dropped from a needle enables one to calculate quickly and accurately from a line chart the hematocrit or hemoglobin values and from the plasma the total proteins of the sample.¹ A set of 4 ounce (120 cc.) bottles containing copper sulfate solutions the specific gravities of which vary from 1.021 to 1.070 is prepared^{1a} At the bedside or the operating table, a drop of venous blood may be dropped into the solution directly from the syringe. For whole blood the normal range of specific gravities is around 1.056 to 1.063 for men and 1.052 to 1.060 for women. For less urgent cases, heparinized or oxalated whole blood may be used for determining specific gravities of whole blood and, after centrifuging, the plasma may be dropped into the solutions to determine the specific gravity of the plasma.

The normal range of plasma for men and women is 1.028 to 1.024. Great care must be used in preparing the solutions and in preparing the oxalated tubes for collecting the blood samples, in order to have accurate results.

The blood is dropped from a needle or pipet from a height of 1 cm above the surface of the solutions. The solution the specific gravity of which is identical with that of the blood or plasma used will cause the drop to hesitate toward the center of the solution for about ten seconds, then slowly descend to the bottom.

Determinations were made for all patients soon after admission and at frequent intervals thereafter, particularly during the course of plasma and whole blood transfusions. For example, determinations were always made after two thirds of the estimated amount of blood required had been given, this enabled a reevaluation of the blood needs more accurately.

RESULTS

The copper sulfate method was found to have the great advantage of simplicity. It could be used at the bedside of the patient, in the operating room or in clinical laboratories. The actual determination was usually made clinically at the bedside, but if large numbers of patients were involved the specimens were collected in oxalated bottles for determination in the laboratory.

Correlations.—The results obtained by the copper sulfate method compare favorably with those obtained by photoelectric determination of hemoglobin, as is shown in table 1. There was also a good relation

¹ Phillips, R. A., Van Slyke, D. D., Dole, V. P., Emerson, K., Jr., Hamilton, P. B. and Archibald, R. M. The Copper Sulfate Method for Measuring Specific Gravities of Whole Blood and Plasma, Bull U. S. Army M. Dept., December 1943, no. 71, p. 66, New York, Josiah Macy, Jr. Foundation, 1945, Chicago, E. H. Sargent and Co., 1946.

^{1a} E. H. Sargent and Company, 155 East Superior St., Chicago, are national distributors of the special copper sulfate crystals and standards needed for these estimations. The solutions used in the studies reported here were made up in accordance with the instructions of Phillips and others.¹

between the specific gravity of the plasma and Kjeldahl analyses for total proteins, as shown in table 2. The method was found to be accurate to plus or minus 0.1 Gm of protein per hundred cubic centimeters of plasma with not over 0.3 Gm variation. It did not appear that shock or other allied conditions affected the accuracy. In normal

TABLE 1—Comparative Data on Hematocrit and Hemoglobin Values Obtained by Different Methods

Specimen	Hemo-globin *	Hemo-globin †	Hematocrit Value (Determined)‡	Hematocrit Value (Calculated)	Red Blood Cell Count
1	11.4	11.0	37.0	34.0	8,090,000
2	12.0	13.5	38.0	40.0	4,010,000
3	12.8	13.4	42.0	38.9	3,620,000
4	12.8	13.2	40.0	42.2	5,250,000
5	12.5	13.0	37.0	39.0	4,230,000
6	11.1	11.4	35.0	34.0	3,980,000
7	11.0	11.3	35.0	33.0	4,480,000
8	15.4	14.0	43.0	39.0	3,890,000
9	12.7	12.8	39.0	37.0	4,260,000
10	15.2	13.8	51.0	49.0	4,600,000
11	11.4	11.9	33.5	35.0	3,810,000
12	14.1	13.2	37.0	39.5	3,620,000
13	14.5	13.8	45.0	40.0	3,960,000
14	12.2	12.8	44.0	38.0	4,010,000
15	12.5	14.2	44.0	42.5	4,000,000
16	18.8	15.8	42.0	45.5	4,280,000
17	18.7	12.7	43.0	37.5	8,890,000
18	12.8	12.7	51.0	51.5	4,700,000

* These values were obtained from the photoelectric determinations of hemoglobin.

† These values were obtained by the copper sulfate method.

‡ Hematocrit values were determined by centrifuging (obtained from Chief of Laboratory Service, Lieut Col Harry Agress).

TABLE 2—Determinations by Copper Sulfate Method

	Healthy Normal Persons					
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Hematocrit value	48.8 (determined 50.2)	50.5	55.0	46.0	50.0	55.0
Hemoglobin	16.6 (photoelectric 16.8)	17.0	17.0	16.5	16.8	18.5
Total plasma protein	7.15	6.8	6.8	7.5	7.15	7.5

and pathologic bloods in which hemoglobin concentration within the red cells is not affected, the hemoglobin content by the specific gravity of whole blood was found regularly to be within 2 per cent of the correct value, as measured by the oxygen-carrying capacity, or plus or minus 0.3 Gm of hemoglobin per hundred cubic centimeters.¹ The discrepancies were greater in determination of hematocrit values than for hemoglobin, but the correlation between the two is illustrated in table 1. This table also shows that red blood cell counts vary considerably

and proved to be a less accurate index of the concentration of red cells. This seemed to be particularly true in patients who were in shock, especially if the count was made from blood taken from puncture of a finger rather than a vein.

The Amount of Blood Given—In calculating the amount of whole blood required by the patient who had suffered severe hemorrhage, the basis was an empiric observation that the transfusion of 500 cc of whole blood increased the patient's hemoglobin concentration by 0.9 Gm. The use of the copper sulfate method, particularly when it

TABLE 3.—Initial Determinations on Admission of One Hundred and Sixty-Six Orthopedic Battle Casualties

Hemoglobin in Grams (Copper Sulfate Method)					12	8	3
15.0							
14.6	15				7	1	
14.1	14.5					7	
13.6	14				8	4	
13.1	13.5				13		
12.6	13			10			
12.1	12.5			18			
11.6	12		8				1
11.1	11.5		1	8			
10.6	11	1	4	3	2		
10.1	10.5	2	16				
9.6	10	4	1				
9.1	9.5	11					
8.6	9	7					
8.1	8.5	6					
7.6	8	3					
7.1	7.5	5					
6.6	7				1		
		20-29	30-32	33-35	36-38	39-41	42-44
						45-47	48-50
							51

was repeated after two thirds of the calculated amount had been given, enabled an accurate estimation of the amount of blood actually required.

In 91 surgical cases, mostly major orthopedic injuries with infected wounds, an average of 2,360 cc of whole blood was given during the four day preoperative and two week postoperative periods. This could be divided into an average of 1,060 cc before and 1,300 cc during and after operation. The copper sulfate method and the rule of giving 500 cc of whole blood for every 0.9 Gm of hemoglobin below the normal 15 Gm per hundred cubic centimeters was used in treating these patients. Also 98 general surgical patients had copper sulfate determinations, and 93 of them received an average of 1,470 cc of whole blood per patient. The amounts ranged from 500 to 6,500 cc per patient. In 27 patients who had similar injuries without appreciable sepsis and

who did not require penicillin, an average of 1,800 cc of whole blood was given in the same period, with but 200 cc of blood plasma needed. There were 7 patients treated for various conditions with penicillin without operation who received only 800 cc of whole blood and less than 1 unit of plasma per patient.

Fifty per cent (89) of 166 casualties had on admission to a general hospital hemoglobin values below 12 Gm despite numerous transfusions (table 3).

One patient with a compound comminuted fracture of the upper third of the left femur and colostomy after an abdominal wound due to a shell fragment had a hematocrit value of 28.5, 9.6 Gm of hemoglobin and 6.13 Gm of total proteins the day of admission. Despite a liter of blood, the values were not much different the next day. A total of 8,150 cc of whole blood was given over a month's time. Rib resection for drainage of empyema and drainage of urine through a wound in the thigh contributed to the need for whole blood. It was only because of the use of a simple accurate method of estimation of blood requirements that it was possible to keep the protein and hemoglobin near normal without undue fluctuation.

Space does not permit a detailed account of the results of each day's copper sulfate determination for these patients.

Two other patients were admitted with fractured femurs and multiple soft tissue wounds. One looked much paler than the other, who did not appear to be anemic. The hematocrit and hemoglobin values in the latter were reduced to about one-half normal, however, while the former had values only one-fourth below normal. This and numerous other instances convinced us that the use of such a method not only enabled us to treat our patients more intelligently, but was a real help in assuring adequate nutrition to promote early wound healing and recovery. Amino acid solutions parenterally were used in a few cases of chronic disease, in addition to whole blood and plasma.

Reactions.—In over two thousand transfusions in a two month period, there were only four reactions due to blood of the wrong type. The transfusions were stopped before more than 50 to 100 cc had been given. The blood was returned to the laboratory and was found, after careful tests, to have been the wrong type. (The transfusions caused no fatality and no apparent renal damage.) This emphasized the value of carefully watching the patient during the transfusion, especially during the first few minutes. Two patients with severe wounds of the ilium and the abdomen died in uremia, present on admission. The effects of blood hematin on the kidneys was found in one, but there was no record of any mismatched blood being given. In the second, the

Rh factor was excluded. The effect of sulfonamide drugs on the renal function was thought to be important from gross examination of the kidneys in these 2 cases, although no crystalline deposits were seen by the pathologist. Further discussion of these problems may be found in the literature.² Whether myohematin from muscle necrosis in large areas in the absence of a tourniquet was a factor is debatable. There is a renal damage from it in crushing injuries.³

A single measurement of the blood pressure is not a good indication of the degree of shock in borderline cases.

COMMENT

The evidence herein presented clearly indicates that the copper sulfate method, when used on whole blood, seems to be just as accurate as hematocrit readings or measurements of hemoglobin concentrations or red blood cell counts. In this way the degree of hemoconcentration which produces an increase in specific gravity as well as hemodilution which produces a decrease in specific gravity can be readily measured. The method can be used readily at the bedside and seems to show, particularly when repeated determinations were made, that the blood requirements of a patient with a definite but stabilized blood volume can be sufficiently accurately determined to be of practical clinical significance. In using these measurements, it was assumed that 500 cc of whole blood will raise the patient's hemoglobin concentration by 0.9 Gm. Actual measurements seem to justify the use of this basic measurement and indeed seem to be more valuable than the use of a modified burn formula, which was also used. Of obvious importance is the type of injury and in particular the question whether the hemoconcentration has occurred after loss of blood or the hemodilution after loss of plasma. In either case a deceptively normal value will be obtained. An important factor was the use of many determinations which changed with the varying clinical conditions and with therapy. A single copper sulfate determination was therefore of little value.

Adams and Ballou⁴ found that in 55 of 128 cases, or 44 per cent, the differences between the total protein values by the copper sulfate

2 (a) McKee, F. W., Laycock, C. F., Martens, T. G., and Nicholl, R. J. Hemorrhagic Shock. The Relative Effect of Saline, Washed Red Cells, and Heparinized Plasma in Dogs, *Surg., Gynec. & Obst.* **78**: 509 (May) 1944. (b) Allen, J. G., Clark, D. E., Thornton, T. F., Jr., and Adams, W. E. The Transfusion of Massive Volumes of Citrated Whole Blood and Plasma in Man. Clinical Evidence of Its Safety, *Surgery* **15**: 824 (May) 1944.

3 Bywaters, E. G. L. Ischemic Muscle Necrosis, *J. A. M. A.* **124**: 1103 (April 15) 1944.

4 Adams, M. A., and Ballou, A. N. A Comparison Between the Values for Plasma or Serum Protein as Obtained by the Specific Gravity and the Micro-Kjeldahl Methods, *J. Lab. & Clin. Med.* **31**: 507 (May) 1946.

and the micro-Kjeldahl methods did not exceed 0.3 Gm per hundred units of serum. This percentage was slightly lower when the albumin was less than normal or the globulin above normal. They used serum instead of plasma for total protein determinations by the copper sulfate method, the routine measurement of the given amount of blood from a syringe by various persons is not accurate in the oxalate method.

Atchley and his co-workers⁵ found a much greater degree of accuracy than Ballou by the copper sulfate method as compared to the micro-Kjeldahl method for total proteins.

These possible criticisms of the method are offset by its accuracy for hemoglobin-hematocrit determinations. In our hands there was sufficient accuracy for total protein determinations to be of definite clinical value.

TABLE 4.—Initial Copper Sulfate Determination for Battle Casualties on Surgical Wards,* Total Proteins, Grams Per Hundred Cubic Centimeters

Hematocrit Value	Total Proteins, Gm per 100 Ce								
	4.0-5.0	5.0-5.5	5.5-6.0	6.1-6.5	6.6-6.7	7.1-7.5	7.6-8.0	8.1-8.6	Total
16-20	0	0	1	0	0	0	0	0	1
21-29	3	2	8	6	3	0	0	0	22
30-32	0	0	8	7	1	1	0	0	17
33-36	0	2	2	18	2	2	1	1	23
37-39	0	0	2	5	1	1	0	0	9
40-42	0	0	0	7	2	1	0	0	10
43-45	0	1	1	3	4	2	0	0	11
46-48	0	1	0	0	1	1	0	0	3
49-51	0	0	0	0	1	0	0	0	1
51-60	0	0	0	0	0	1	0	0	1
Total	3	6	22	41	15	9	1	1	98

* This table was prepared by Pvt J F Burns, from data from laboratory files of Lieut Col Harry Agress.

Normal values were not infrequently found initially in patients with severe wounds and a history of hemorrhage. This paradox is obviously due to hemoconcentration. Should this normal determination be taken at its face value, serious difficulty will ensue because the additional loss of a few hundred cubic centimeters of blood, especially with the added trauma of operation, may be enough to cause the patient to go into shock⁶ (table 4). Clearly, therefore, the history of a case is just as important as the laboratory values. Otherwise, the discrepancy can

5 Atchley, J., Bacon, R., Curran, G., and David, K. A Clinical Evaluation of the Copper Sulfate Method of Measuring Specific Gravities of Whole Blood and Plasma, *J Lab & Clin Med.* 30:830 (Oct.) 1945.

6 Lyons, C. Penicillin Therapy of Surgical Infections in the U.S. Army, *J.A.M.A.* 123:1007 (Dec 18) 1943. Evans, E. I., James, G. W., III and Hoover, M. J. Studies on Traumatic Shock. II. The Restoration of Blood Volume in Traumatic Shock, *Surgery* 15:420 (March) 1944.

only be detected by blood volume determinations. Measurements have been made⁷ on patients soon after injury and have shown that the blood volume is 30 to 40 per cent below normal with clinical manifestations

TABLE 5—Initial Copper Sulfate Determination for Battle Casualties in All Surgical Wards

Hematocrit Value	Total Protein, Gm per 100 Cc						
	5 6-6 0	6 1 6 5	6 6-7 0	7 1 7 5	7 6-8 0	Total	Percentage
29 29	86	55	12	8	2	163	21.2
30 32	83	32	7	1	0	73	9.5
33 35	31	39	26	9	2	107	14.0
36 38	24	61	23	24	3	135	17.5
39 41	16	40	42	15	7	120	15.6
42 44	5	29	35	26	3	98	12.7
45 47	4	11	21	15	3	54	7.0
48 50	0	4	3	8	1	11	1.4
50 60	0	0	3	2	2	7	0.9
Total	199	271	172	103	23	763	
Percentage	26	35	22.4	13.4	3		

TABLE 6—Determinations of Total Proteins* (Heparinized Samples)

Specific Gravity, Copper Sulfate Method	Bluret Method Checked with Micro Kjeldahl Method	Difference Between the Methods
7.4	7.0	0.4
6.8	6.8	0.0
6.9	6.0	0.1
6.8	6.7	0.1
6.3	6.6	0.3
6.4	6.3	0.1
8.2	8.2	0.0
5.7	5.8	0.1
5.5	5.7	0.2
7.4	7.7	0.3
7.5	7.6	0.1

Heparinized blood gave consistently higher values than oxalated blood for total proteins and hematocrit values for the same sample of blood in the same laboratory. Oxalate bottles with average amounts of oxalate such as are prepared routinely in most hospitals may cause a decrease in plasma specific gravity unless the kind and amount of oxalate and amount of blood added are carefully controlled.

* Obtained with the help of Dr. Robert King

of shock following skeletal trauma and/or hemorrhage. It was also found that on the average 1.5 to 2 liters of blood was required for replacement. The conditions responsible for hemoconcentration and

⁷ Noble, R. P., and Gregerson, M. I. Blood Volume in Clinical Shock, II The Extent and Cause of Blood Volume Reduction in Traumatic, Hemorrhagic, and Burn Shock, J Clin Investigation 25: 172 (March) 1946.

hemodilution must be carefully differentiated on a clinical basis⁸. In most skeletal trauma with simple hemorrhage, the loss of blood is associated with hemodilution (table 5). On the other hand, in burns and abdominal injuries with peritonitis, selected loss of plasma occurs at the site of injury or infection and the ensuing reduction in blood volume is attended by hemoconcentration⁷. In addition, however, there is probably some other factor than local loss of fluid, particularly in the case of so-called tourniquet or crush syndrome⁹.

In the care of these patients, the value of a roving consultant trained in the intricacies of preoperative and postoperative care proved of great value for patients during critical phases of treatment. Entirely apart from the use of blood and plasma the nutritional intake was found to be extremely important, and measures were taken to insure an intake of at least 70 Gm of protein daily, and from 120 to 140 Gm of proteins daily in many patients, in order to prevent depletion of protein reserves during convalescence¹⁰.

During these observations no evidence of toxic effects from the use of citrated blood was observed. In dogs, the toxic dose was found to be 0.3 Gm per kilogram of body weight^{2b} when given in fifteen minutes or less. Most of our patients got 0.1 to 0.3 Gm per kilogram in two or more hours, inasmuch as each 500 cc flask of blood contains 70 cc of 2.5 per cent sodium citrate solution.

SUMMARY

This report is based on a study of 166 patients admitted to a general hospital overseas for whom a simple, accurate copper sulfate specific gravity method was used to determine hemoglobin and hematocrit values as well as concentration of total proteins. The values obtained were found to check closely with determinations obtained by more orthodox methods. Blood needs could be readily calculated on a basis that 500 cc of whole blood increased the hemoglobin 0.9 Gm. Fluid balance must be restored and dehydration corrected before this rule of thumb can be applied literally.

An average of 2,360 cc of whole blood was required during a four day preoperative and a two week postoperative period. In 98 cases of

8 Elman, R., Lischer, C. E., and Davis, H. W. Plasma Proteins (Albumin and Globulin) and Red Cell Volume Following a Single Severe Non-Fatal Hemorrhage, *Am J Physiol* **138** 569 (March) 1943.

9 Scott, C. C. Failure of Local Fluid Loss to Account for Death in Experimental Shock, *J Clin Investigation* **25** 153 (March) 1946.

10 Nutritional Aspects of Convalescent Cases Report of Committee on Convalescence and Rehabilitation of the National Research Council Bull U S Army M Dept, May 1944, no 76, p 85.

less severe disease an average of 1,470 cc of whole blood was required per patient during a similar period.

When admitted to the hospital, half of all patients had hemoglobin values below 12 Gm and total proteins below 6.6 Gm, and 69 per cent of the patients had hematocrit readings below 40. Changes in these values, particularly before and after therapy, proved of even greater value than the initial measurement.

The copper sulfate specific gravity method of determining hemoglobin, hematocrit and total proteins with the use of a line chart proved to be simple, yet accurate enough for clinical use.

Robert Elman, M.D., gave helpful criticism during the final writing of this paper.

NOTE.—In normal and miscellaneous medical patients, Dr R. A. Phillips and others, comparing the gravities with plasma proteins estimated by exact macro-Kjeldahl analyses, have shown statistically that the most precise results for such plasmas are calculated by the equation $P = 389.6 (G_p - 1.0079)$. This gives plasma protein concentrations about 0.2 Gm per hundred cubic centimeters higher than the equation used previously and the line charts 1 and 2.

TOTAL GASTRECTOMY

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BY DEFINITION total gastrectomy is the removal of the entire stomach along with a cuff of esophagus, above, and of duodenum, below. Such an operation has now become accepted as a recognized surgical procedure for the treatment of certain lesions of the stomach which cannot be dealt with adequately by partial or subtotal gastrectomy. The lesions which most often require complete gastrectomy are those carcinomas or lymphosarcomas which involve the greater part of the stomach. From the technical standpoint the small "leather bottle" stomach, or *linitis plastica*, due to a diffuse infiltrating scirrhouss carcinoma, has generally been regarded as the type best suited to this operation. In addition, smaller malignant neoplasms situated in the upper half or upper third of the stomach are best treated by total gastrectomy. Large neurofibromas or leiomyomas with or without sarcomatous degeneration which extend into the upper portion of the stomach are particularly favorable for cure, since, in spite of their large size, these tumors are either benign or of a low grade of malignancy. Juxtaesophageal gastric ulcer, if dealt with by gastric resection by the abdominal route, is best managed by complete gastrectomy, since conservation of the lower portion of the stomach is unnecessary, and probably undesirable, and adds considerably to the difficulties of a satisfactory reconstruction.

As experience with total gastrectomy in many surgical clinics has increased the technical details of the procedure have become fairly well standardized. This, with the many advances in preoperative and postoperative care which have been made during recent years and the many suitable methods of anesthesia now available, has resulted in a reduction of the operative mortality to a level which, while still disturbingly high, is nevertheless not prohibitive. Moreover, sufficient follow-up studies have been made on patients who have survived the operation to indicate that a person may live a reasonably normal and comfortable life in the complete absence of the stomach.

From the Department of Surgery, University of Michigan

Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association,
Memphis, Tenn., Dec 6, 1946

In an exhaustive review of the literature in 1929, Finney and Rienhoff¹ collected 62 cases of total gastrectomy and added 5 of their own. There were 36 operative deaths in these 67 cases, or an operative mortality of 53.8 per cent. The longest period of survival after operation in this series was four years and eight months. In 1938 Allen² reported 16 cases of total gastrectomy from the Massachusetts General Hospital and emphasized certain technical details which he considered important for the success of the operation. These were, (1) restoration of gastrointestinal continuity by esophagojejunostomy rather than an attempt at esophagoduodenostomy, (2) attachment to the diaphragm of the loop of the upper portion of the jejunum used in the anastomosis in order to prevent strain on the suture line, (3) enteroenterostomy between the afferent and the efferent limb of the jejunal loop, (4) catheter jejunostomy for feeding during the early postoperative period, and (5) maintenance of suction from within the esophagus during the time that this structure is open by means of a Levine tube connected with the Wangensteen suction apparatus. His operative mortality was 50 per cent. The longest period of survival following operation was four and one-half years. In a recent communication Allen³ (1946) presented data on the entire series of total gastrectomies for cancer performed at the same hospital. There were 84 cases, in 30 of which operation was performed by the trans-thoracic route. The over-all mortality rate for the entire series was 40 per cent. One patient had survived ten and a half years, and another five and a half years, without signs of recurrence. Lahey and associates,⁴ in several articles on this subject, emphasized certain technical details, notable among which was the development of anterior and posterior peritoneal flaps from the diaphragm to be sutured over the anastomosis on its completion, thereby minimizing the danger of leakage and reducing tension. Lahey stated that he invariably employs an antecolic esophago-jejunal anastomosis. In his most recent paper (1946)⁵ he reported 89 cases, with 26 deaths, an operative mortality of 29.2 per cent.

1 Finney, J M T, and Rienhoff, W F, Jr. Gastrectomy, Tr South S A 40 424, 1927

2 Allen, A W (a) Carcinoma of the Stomach, with Special Reference to Total Gastrectomy, Ann Surg 107 770, 1938, (b) Total Gastrectomy for Carcinoma of the Stomach, Am J Surg 40 35, 1938

3 Allen, A W Personal communication to the author, November 1946

4 Lahey, F H Complete Removal of the Stomach for Malignancy Report of Five Surgically Successful Cases, Surg, Gynec & Obst. 67 212, 1938 Lahey, F H, and Marshall, S F Combining Splenectomy with Total Gastrectomy ibid 73 341, 1941, Indications for, and Experiences with, Total Gastrectomy, Based upon Seventy-Three Cases of Total Gastrectomy, Ann Surg 119 300, 1944

5 Lahey, F H Gastric Surgery, New England J Med 234 809, 1946

although during the last three and one-half years the mortality had fallen to 16.3 per cent His oldest living patient was alive and well eight years and seven months after operation, the procedure having been performed for a large leiomyosarcoma involving all the stomach His follow-up studies indicate that of the patients who survive the operation 59.7 per cent will live twelve months, 38.6 per cent eighteen months, 29.8 per cent twenty-four months and 21.1 per cent thirty-six months or more

Jones and Kehm⁶ (1945) reported 8 consecutive cases of total gastrectomy, with no deaths These patients were all living from six to eighteen months after the operation In 1943 Pack and McNeer⁷ reviewed all the cases reported in the literature up to July 1, 1942 and added 20 of their own In these 20 cases there were 6 deaths, or an operative mortality of 30 per cent In considering the total number of 303 cases assembled, it was observed that prior to 1921 the mortality was 49.3 per cent, whereas from 1921 to 1930 it was 31.6 per cent and from 1931 to 1942 it was 34.3 per cent In their own group of patients, 1 was alive and well two years and eight months after operation Horsley⁸ (1943) reported successful results in 3 consecutive cases of complete gastrectomy Prior to this he had performed the operation in 12 cases with a fatal outcome in all Graham,⁹ having had unsatisfactory results with the usual methods of esophagojejunostomy in his earlier experience, described an ingenious method of enclosing the anastomosis between the afferent and the efferent jejunal limb which had given good results in his hands This technic has since been adopted by many surgeons

MATERIAL

During the nine year period from October 1937 to October 1946, complete gastric resection was performed by the abdominal route in 60 cases¹⁰ The gastric lesions for which the procedure was carried out are listed in table 1 Of the 60 patients, 41 were men and 19 women The oldest patient in the series was 81 and the youngest 30 years of age, the average age being 55 years

6 Jones, T E, and Kehm, R W Total Gastrectomy Report of Eight Cases, *Surg, Gynec & Obst.* **80** 534, 1945

7 Pack, G T, and McNeer, G Total Gastrectomy for Cancer A Collective Review of the Literature and an Original Report of Twenty Cases, *Internat. Abstr. Surg.* **77** 265, 1943, in *Surg, Gynec & Obst.*, October 1943

8 Horsley, J S Three Successful Cases of Total Gastrectomy, *Virginia M Monthly* **70** 549, 1943

9 Graham, R R Technique for Total Gastrectomy, *Surgery* **8** 257, 1940

10 Since the completion of this paper, total gastrectomies have been successfully performed for cancer in 2 additional cases

Carcinoma—As in all the previously reported series, carcinoma provided the most common indication for the operation, and it was for this lesion that the procedure was performed in 53 of the cases. In the experience of my associates and myself, three types of lesions have been encountered which have required removal of the entire stomach (fig 1).

(a) Lesions which involve all, or nearly all, of the stomach. This group includes both the small "leather bottle" stomach, due to infiltrating scirrhous carcinoma, and the large adenocarcinomas, which in some instances may have invaded the greater part of the gastric wall and still have not extended grossly beyond the stomach except for involvement of the regional lymph nodes along the two curvatures (fig 2).

(b) Smaller lesions situated high on either curvature or on the anterior or posterior wall in such a manner as to make adequate resection impossible except by removal of the lower end of the esophagus (fig 3).

TABLE 1.—*Lesions of the Stomach for Which Total Gastrectomy Was Performed on Sixty Patients*

Lesion	No of Patients	No of Operative Deaths	Mortality, per Cent
Carcinoma	53	12	22.6
Gastric ulcer	4	1	25
Lymphosarcoma	2	1	50
Neurofibroma	1	0	0
Total	60	14	23.3

(c) Sessile or polypoid lesions occurring in the lower or middle portion of the stomach but with indefinite intramural extension cephalad, as evidenced by thickening and friability of the gastric wall proximal to the lesion. On some occasions this proximal involvement was detected only when the stomach was transected for a proposed subtotal resection. In doubtful cases specimens taken at this level for microscopic examination of frozen sections will usually clarify the situation.

The operative mortality in this group of 53 cases was 22.6 per cent.

Lymphosarcoma—The problems presented by lymphosarcoma of the stomach are essentially the same as those of carcinoma. This lesion, while of relatively rare occurrence, requires the same radical treatment. There were 2 cases of this tumor in the present series. In 1 case the growth involved the entire stomach and had extended into the pancreas, and the regional lymph nodes were extensively involved. In view of this fact, a course of irradiation was given after operation, but the patient died exactly six months later as a result of generalized lymphoblastomatosis. In the second case the lesion was confined to the

upper half of the stomach and there was involvement of some of the regional lymph nodes. This patient died on the third postoperative day. Autopsy revealed that death was caused by general peritonitis, due to partial separation of the esophagojejunial anastomosis. Lymph

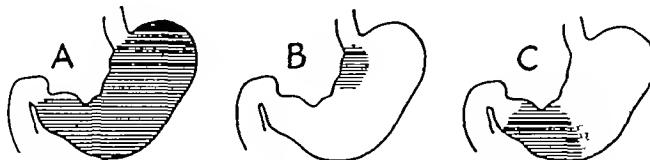


Fig 1.—Diagram showing extent of involvement of the stomach by malignant lesions treated by total gastrectomy, 55 cases. A, lesions involving all, or nearly all, of the stomach, 36 cases; B, smaller lesions situated in the upper half of the stomach, 11 cases; C, lesions in the lower portion of the stomach with indefinite extension upward, due to intramural spread, 8 cases.



Fig 2.—A, typical roentgenologic appearance of diffusely infiltrating scirrhous carcinoma of the stomach (limitis plastica), showing a small, tubular stomach. Fluoroscopic study showed that the stomach emptied rapidly. In serial roentgenograms there was no evidence of peristaltic waves.

B, roentgenogram made four months after operation, showing partial obstruction at the site of the esophagojejunial anastomosis. A second operation revealed this to be due to extensive recurrence of the neoplasm.

nodes in the mesentery were observed to contain foci of lymphosarcoma, indicating the desirability of postoperative irradiation in all cases of this neoplasm.

Benign Tumors—There was only 1 case of total gastrectomy for benign gastric tumor in this series. This case was that of a woman aged 40 who in June 1938 had a total gastrectomy for a large hourglass neurofibroma involving the entire lesser curvature of the stomach. She is living and in a good state of nutrition at the present time, eight years and four months after the operation. Metabolic studies made four years after operation have been reported in detail.¹¹ Since that pub-



Fig 3.—Preoperative roentgenogram showing extensive involvement of the upper half of the stomach by carcinoma. The lesion was situated chiefly along the greater curvature and the posterior wall. This patient is in excellent health, eight years after total gastrectomy.

lication the patient has been carefully followed, and no important changes have been noted.

Gastric Ulcer—In 4 cases a chronic benign gastric ulcer was treated by total gastrectomy. In all cases there was an ulcer high on the lesser curvature or the posterior wall, and the lesion had originally been

¹¹ Farris, J. M., Ransom, H. K., and Coller, F. A. Total Gastrectomy Effects upon Nutrition and Hematopoiesis, *Surgery* **13** 823, 1943.

diagnosed as benign on the basis of roentgenographic and gastroscopic studies (fig 4) Intensive medical treatment over a prolonged period failed to result in healing, and its malignancy was accordingly suspected At the time of operation, the lesions were observed to be penetrating ulcers, and their malignant character could not be excluded Since gastric resection seemed mandatory in view of the high position of the lesion total gastrectomy was elected There was 1 fatality in this group The final microscopic studies showed that all the lesions were benign In view of this mortality of 25 per cent, it would seem that complete gastrectomy is probably not the best procedure for such a juxtaesophageal ulcer On the other hand, palliative gastrectomy, as recommended by Colp,¹² leaves a possibly malignant lesion in situ, as would also simple gastroenterostomy or transthoracic vagotomy Possibly, local excision of the ulcer combined with gastroenterostomy or trans-

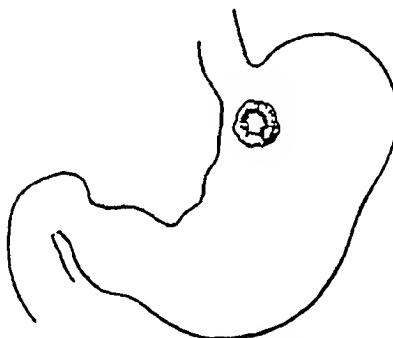


Fig 4.—Benign juxtaesophageal gastric ulcers treated by total gastrectomy, 4 cases

thoracic resection of the upper portion of the stomach with its contained ulcer, according to the suggestion of Sweet,¹³ would be superior and safer

TECHNICAL CONSIDERATIONS

Preliminary Preparation—Since most patients with gastric lesions evince signs of serious nutritional disorders, with dehydration, anemia and avitaminosis, a fairly long period of preparation is necessary for their rehabilitation Blood transfusions are used freely, and ascorbic acid and vitamin B complex are administered in large quantities Vitamin K is added if there is a prothrombin deficiency Particular attention to oral hygiene is important, since contamination of the operative field by oral secretions inevitably occurs to some degree, inasmuch as an aseptic type of anastomosis between the esophagus and the jejunum is not feasible A preliminary course of sulfadiazine or penicillin for a few days prior to operation probably affords additional protection Care should be exercised in minimizing the amount of preoperative sedation The patient comes to the operating room with an indwelling Levine tube in the stomach, and this is attached to the

¹² Colp, R., and Druckerman, L. J. Palliative Gastrectomy in Selected Cases of Gastric Ulcer, Ann Surg 124:675, 1946

¹³ Sweet, R. H., in discussion on Colp and Druckerman¹²

Wangensteen suction apparatus so that suction can be maintained during the operative procedure. A needle is placed in an arm vein before the operation is started so that the proper fluids may be given continuously.

Anesthesia—Good relaxation is essential in providing satisfactory exposure and in minimizing the difficulties of the esophagojejunal anastomosis. Spinal anesthesia was used in a number of cases, with satisfactory results. However, unless some type of continuous spinal anesthesia is used, in view of the long duration of the operation, it will ordinarily be necessary to resort to inhalation anesthesia for the latter part of the procedure. Endotracheal anesthesia induced with a nitrous oxide-oxygen-ether mixture has been found entirely adequate, and more recently endotracheal cyclopropane anesthesia aided by curare has proved satisfactory.

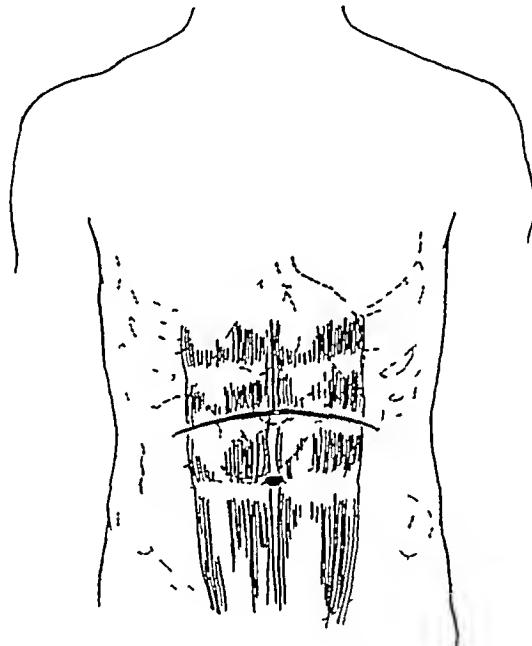


Fig 5.—Incision recommended for total gastrectomy.

Incision—An upper abdominal, slightly curved, transverse incision which transects both rectus muscles is now employed for practically all gastric operations in this clinic. Such an incision affords adequate exposure for total gastrectomy in many cases. If additional room is required, a vertical extension is added, the incision passing upward through the linea alba to the ensiform process (fig 5). Closure, except for the peritoneum, is made with nonabsorbable suture material, stainless steel wire or silk being preferred. Wound infections have occurred somewhat more frequently with this than with the usual type of abdominal operation. In 1 instance a severe wound infection occurred and resulted in a large incisional hernia, which required surgical repair several months later. It is now deemed advisable to employ the method of delayed primary closure of the wound (Coller and Valk¹⁴) in most cases.

¹⁴ Coller, F. A., and Valk, W. L.: The Delayed Closure of Contaminated Wounds, *Ann. Surg.* **112**: 256, 1940.

Operative Procedure—In 57 cases the operative technic described by Allen was followed^{2b} (fig 6). In this operation a retrocolic anastomosis is preferred whenever possible, and it was employed in 52 cases in this series. Antecolic anastomosis was used in only 5 cases, in each of which certain anatomic peculiarities made the posterior connection impracticable. Whether an enteroenterostomy between the afferent and the efferent jejunal limb is essential is problematic. The anastomosis was performed in 30 cases and omitted in 27 cases. Little difference was noted in the convalescence and subsequent postoperative course in these two groups of patients. In a few cases in which no enteroenterostomy was performed and in which regurgitation or difficulty in eating persisted or occurred later, an adequate explanation was invariably found in other lesions, such as recurrent neoplasm or subphrenic abscess. The theoretic advantages of an enteroenterostomy, which have been mentioned, are the reduction in tension in the proximal jejunal loop during convalescence, which may safeguard the main anastomosis and the closed

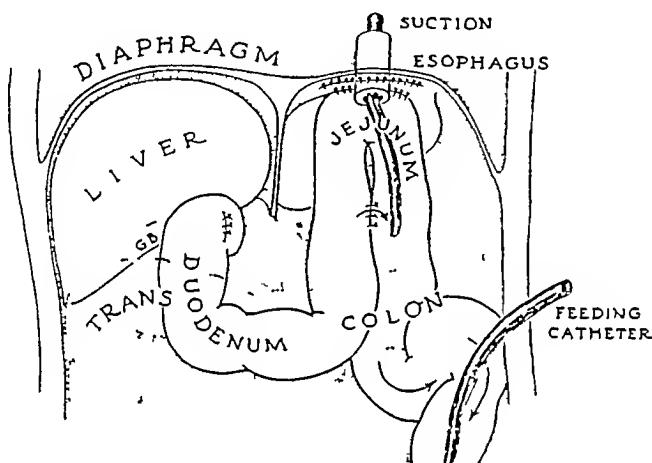


Fig 6.—Diagrammatic sketch showing operation completed (redrawn from Allen^{2b})

duodenal stump, and the prevention of duodenal contents from entering the esophagus, a possible source of annoying pyrosis.

The method of reconstruction following removal of the stomach advocated by Graham was employed in only 3 cases. Graham recommended use of an antecolic anastomosis, and the enteroenterostomy in this operation is mandatory. In 2 cases the postoperative course was entirely smooth and uneventful, whereas in the third case, that of resection for ulcer, the patient died on the seventh postoperative day. Autopsy disclosed that death was due to volvulus of the proximal jejunal limb, with gangrene and multiple points of perforation and resultant general peritonitis. Horsley reported a similar accident and now advises anchoring the proximal limb of the jejunum to the duodenum.

A catheter jejunostomy for early postoperative feeding was employed in 49 cases and omitted in 11 cases. This simple expedient, in our opinion, is distinctly worth while. It requires only a few additional minutes at the time of operation for its establishment, and it simplifies the postoperative care in all cases. If complications at the esophageal anastomosis, such as obstruction or leakage, occur, it is of inestimable value. In a few instances in which a jejunostomy was not performed at the time of operation it became necessary to establish one as a

secondary operation. No difficulty has been encountered with persistent fistula or intestinal obstruction at the jejunostomy site.

Splenectomy often facilitates the operative procedure by improving the exposure. For this reason it is often performed, and it is also indicated when there is involvement by neoplasm of the spleen or the lymph nodes at the hilum. An additional indication for splenectomy is the troublesome bleeding occasionally encountered owing to laceration of the capsule or tearing of the organ. Retorally, splenectomy is to be avoided, since the danger of postoperative thrombocytopenia is increased. In this series it was performed in 24 cases, whereas it was unnecessary in the remaining 36 cases. In the cases in which the spleen was removed, no complications were noted which could be attributed to this procedure.

As the esophagojejunal anastomosis is completed, the Levine tube is withdrawn down into the distal jejunal loop, and the Wangensteen suction is continued throughout the operation. It is believed that the aspiration of fluid minimizes tension at the suture line, and the splinting effect of the tube is probably desirable. This tube is now removed on the third or fourth day, as its prolonged use may result in ulceration or necrosis at the suture line, as well as involving danger of tracheal or of the cricoid cartilage. No attempt is made to give liquids or feeding through the tube, although the occasional instillation of a small amount of fluid is desirable in order to make certain that the tube has not become plugged by mucosal foldings caught in the openings.

My colleagues and I have discontinued almost entirely the local use of sulfonamide drugs in the peritoneal cavity. Preferable to this, we believe, is a massive dose (80,000 to 100,000 units) of penicillin administered intravenously during the conclusion of the operation. Penicillin is continued in a dose of 40,000 units every three hours for several days after operation, or longer if indicated. A transfusion of at least 1,000 cc of blood is given during the course of the operation, and additional blood is given during the postoperative period if necessary.

PATHOLOGIC STUDY

In the group of cases here reported total gastrectomy was ordinarily elected only when at the time of operation there seemed to be a reasonable chance for cure. In most cases, therefore, the problem was one of that of the local lesion and the involved regional lymph nodes. In none of the cases were there recognizable hepatic metastases, although in only a few cases were there small secondary deposits of tumor at other points in the abdominal cavity. Thus, the operation was not frequently employed as a definitely palliative procedure, since the present mortality would scarcely justify it. Subsequent events, however, have demonstrated that the operation was actually a palliative one in the majority of cases, as evidenced by the fact that 31 of the 42 patients with malignant disease who survived the operation have subsequently died. In these instances death was due to recurrence, as far as can be ascertained. Microscopic study of the specimens removed at operation disclosed several points of interest. Involvement of the regional lymph nodes was noted in both the cases of lymphosarcoma and in 36 of 46 cases of carcinoma in which a sufficiently careful study was made. In addition to examination of the usual sections taken from the

neoplasm, special studies were made of tissue taken from both the upper and the lower end of the operative specimen in 44 cases of carcinoma. It was disappointing to note that submucosal infiltration by neoplasm was present in the esophageal end up to the line of transection in 21 cases whereas similar involvement of the duodenal end was noted in 13 instances (table 2). These data would indicate that

TABLE 2.—*Microscopic Observations in Cases of Carcinoma of Stomach Removed by Total Gastrectomy*

Ends of specimen (44 cases)	No. of Cases
Part of stomach *	
Upper +, lower —	14
Upper —, lower +	6
Both ends —	17
Both ends +	7
Involvement of regional lymph nodes (46 cases)	
Malignant tissue present	36
Nonmalignant tissue	10

* The plus sign indicates neoplastic infiltration; the minus sign, absence of neoplastic infiltration.

TABLE 3.—*Causes of Death* After Total Gastrectomy for Malignant Growths*

Cause of Death With Autopsy (12 Cases)	No. of Cases
Peritonitis (leak at esophagojejunial anastomosis)	7
Peritonitis (no leaks)	2
Pulmonary embolism and pneumonia	1
Subphrenic abscess	1
Volvulus of proximal jejunal loop (Graham operation)	1
Without Autopsy (2 Cases)	
Peritonitis (leakage at an esophagojejunial anastomosis)	1
Pneumonia	1

* The operative deaths numbered 14, with a mortality rate of 23.3 per cent.

a high rate of recurrence was to be expected, and such proved to be the case. In view of these observations, it is possible that total gastrectomy by the transthoracic route may in the future prove to be a superior type of procedure, since a longer segment of esophagus can be included in the resection.

OPERATIVE DEATHS

There were 14 operative deaths, or a mortality of 23.3 per cent. Postmortem examinations were made in 12 of these cases (table 3). The most frequent cause of death was general peritonitis, as it was demonstrated in 10 instances, and there was convincing clinical evidence that it was responsible for the fatal outcome in 1 of the cases in which autopsy was not performed. The most frequent source of the peritonitis

was leakage at the esophagojejunal anastomosis in 7 of the cases in which autopsy was done. In all the peritonitis all the suture lines were observed to be intact. As previously mentioned, the peritonitis occurred in 2 cases and gangrene of the proximal jejunal loop was present in 1 case. There was no evidence of reconstruction. In 1 case death occurred 10 days after operation and was due to bilateral pulmonary emboli. This complication undoubtedly was due to a slow thrombus formation. It was gratifying to note that pulmonary emboli were the cause of death of only 2 patients.

Autopsy studies in the 11 cases of disseminated malignant growths provide certain interesting findings. In one case of lymphosarcoma residual foci of lymphoma were found in the mesenteric lymph nodes and this was attributed to failure of postoperative irradiation. In all cases of disseminated cancer there was evidence of metastatic disease at autopsy. In 1 case residual metastatic disease was found in the abdominal periaortic, peripancreatic areas, and in the liver as well as in one ovary. In the second case metastatic disease was present in the peripancreatic adipose tissue.

POSTOPERATIVE COURSE

Early Part of Course—Barring cases of disseminated malignant growths, the postoperative course in most patients developed smoothly and uneventfully. In 1 case of subtotal gastrectomy wound sepsis occurred more frequently than expected. In 1 case a left subphrenic abscess developed and required drainage. Serious pulmonary complications were infrequent. I attribute to early recognition of postoperative respiratory distress to early recognition of postoperative respiratory distress and treatment by suction bronchoscopy or intubation as recommended by Haight and me.¹⁵ Frequently, before the operative procedure, bronchoscopic aspiration was performed in the operating room when there was evidence of respiratory distress.

The Levine tube is usually removed on the second day if the patient allowed to begin taking small amounts of liquid food. There is rapid progression to the usual diet for patients with a normal stomach. The jejunostomy tube is removed on the third day if the patient is able to take liquids and are allowed to be up and about as early as possible.

ence has shown that an adequate daily caloric intake may be difficult to attain early in convalescence they are instructed at the time of discharge to take frequent, relatively small feedings. With the passage of time most patients will be able to resume a fairly normal routine so far as eating habits are concerned and will maintain a satisfactory state of nutrition. Ferrous sulfate is prescribed, and its use should be continued indefinitely in order to prevent the development of hypochromic microcytic anemia a condition which frequently follows gastrectomy, owing to interference with the metabolism of iron.

Late Part of Course—After leaving the hospital, a few patients have experienced some difficulty in swallowing. The majority have no trouble of this sort. If the dysphagia is due to slight contraction at the stoma, a few gentle dilations with Hurst dilators will promptly remedy the situation. When symptoms have persisted, the cause has always been due to recurrence involving the stoma. One patient has experienced difficulty with regurgitation after eating for over a year following operation. Roentgenologic studies show a satisfactory stoma, but pronounced hypomotility of the small intestine is present. The case is unique in our experience. In only 2 cases has macrocytic anemia developed. In these cases symptoms did not become manifest until four and one-half and five and one-half years after operation. Studies of the blood revealed the typical changes of pernicious (addisonian) anemia, and prompt remission followed appropriate therapy.

Spontaneous hypoglycemia has been shown by Conn and Ricketts¹⁶ and others to occur fairly often after total and subtotal gastrectomy. It only rarely is responsible for troublesome symptoms and is controlled with a high protein, low carbohydrate diet. A patient who has otherwise done well for over five years after a total gastrectomy for gastric ulcer continues to have distressing symptoms. In addition to the abnormal blood sugar curve, he presents serious psychiatric problems, and it is felt that his poor health is chiefly due to these factors.

END RESULTS

Forty-six of the 60 patients who were treated survived the operation, and of this number 31 have subsequently died. The latter group of patients, now dead, includes 1 patient with lymphosarcoma who survived for six months and 30 with carcinoma. The 3 patients who were successfully operated on for gastric ulcer and the 1 operated on for benign tumor are all living. Table 4 summarizes the duration of life following discharge from the hospital of the patients who died. Death was due to recurrence of the disease in all instances. Approximately

¹⁶ Conn, I. H. and Ricketts, W. Unpublished data.

one-third lived for six months or less, one-third, from six months to one year, and one-third, for more than one year. The average duration of life in this group was ten and one-half months.

In table 5 data are given concerning the 11 patients who were operated on for carcinoma and who are still living. It will be noted that one half of them were operated on too recently for evaluation of the results. Two of these patients already exhibit signs of recurrence.

TABLE 4.—*Postoperative Course of Thirty-One Patients Who Survived Total Gastrectomy and Subsequently Died**

Survival Period	No of Patients
6 mo or less	10
6 to 12 mo	9
12 to 18 mo	10
18 to 24 mo	1
Over 2 yr	1

* Thirty patients had carcinoma and 1 patient lymphosarcoma. The longest survival period was two years four and one-half months, the shortest survival period, two months; the average survival period, ten and one-half months.

TABLE 5.—*Data on Eleven Patients Still Living After Total Gastrectomy for Carcinoma*

Patient No	Sex	Present Age, Yr	Period	Result
1	M	57	7 yr 11 mo	Excellent
2	F	71	6 yr 1 mo	Good (macrocytic anemia)
3	M	64	4 yr 5 mo	Good
4	F	39	1 yr 6 mo	Good (regurgitation)
5	M	70	1 yr 5 mo	Good
6	M	57	8 mo	Good
7	M	64	6 mo	Poor (recurrence)
8	F	40	6 mo	Good (recurrence)
9	M	58	3 mo	Good
10	F	81	3 mo	Good
11	M	62	1 mo	Good

Two patients have survived for eighteen months and are doing fairly well at present. Three of the 41 survivors of the operation for cancer may be regarded as representing five year cures. According to Walters, Gray and Priestley,¹⁷ the death rate among patients who are operated on for gastric carcinoma and who survive for five years is essentially the same as that for the general population.

The most interesting case in this group is that of a man now 57 years old who was operated on eight years ago for a large adenocarcinoma involving the upper half of the stomach (fig. 3). The regional

¹⁷ Walters, W., Gray, H. K., and Priestley, J. T.: Malignant Lesions of Stomach. Importance of Early Treatment and End Results, *J. A. M. A.* **117**, 1675 (Nov. 15) 1941.

lymph nodes removed with the operative specimen showed metastases, in addition, nests of tumor cells were noted in the lymphatics and the blood vessels. This patient is now in excellent health, carries on with his usual occupation, has returned to normal eating habits and maintains an excellent state of nutrition.

In the second case, a woman, now 71, has survived over six years after operation for a scirrhouous adenocarcinoma involving the greater portion of the stomach. In this case the regional lymph nodes were not involved. She did well for four and one-half years after operation whereupon typical macrocytic anemia developed. This has responded well to treatment.

In the third case, a man, now 64, is alive and well approximately five years after operation. In this case there was a fairly localized carcinoma of the antrum and pronounced thickening of the proximal gastric wall, which extended up to the esophagus. At operation this was interpreted as a mural extension of the carcinoma, and a total gastrectomy was performed. Subsequent microscopic study of the tissue showed that the thickening was the result of severe hypertrophic gastritis, which was coexistent with the carcinoma. The regional lymph nodes showed no metastases. The good result obtained in this case suggests that, other factors being equal, better results might well be obtained in many cases of the smaller gastric carcinomas with total rather than with the usual subtotal gastrectomy.

In general, the end results are essentially the same as those reported from many clinics for the entire series of gastric carcinomas treated by the usual methods. While the results are not brilliant they seem to indicate that the operation is worth while in a sufficiently large number of cases to warrant continuation of its use. The small number of patients salvaged would most certainly be lost without treatment. Admittedly, in the case of patients who survived for only a few months the value of the procedure is questionable. However, when life is prolonged for a year or more, the respite from symptoms which usually occurs would seem to make the operation worth while. In following a group of patients with untreated carcinoma of the stomach, Cheever¹⁸ found that only 9.2 per cent lived six months or more after the diagnosis was made, and in nearly 40 per cent the length of life from the time of onset of symptoms until the time of death was only six months or less. The distressing symptoms of patients who die of untreated gastric carcinoma during the natural course of the disease are, unfortunately, familiar to all, and for this reason alone heroic attempts at palliation are to be encouraged.

¹⁸ Cheever, D. The Operative Curability of Carcinoma of the Stomach. Ann Surg 78:332, 1923.

The results following total gastrectomy for benign lesions have been uniformly good (table 6) Our longest period of survival following this operation was eight and one-half years, in the case of a woman operated on for a large neurofibroma There has been no evidence of recurrence of the neoplasm, which was one which recurs locally unless completely excised

One of the 3 patients with gastric ulcer treated by this method has obtained an excellent result He is entirely free from symptoms and is leading a normal life, four and one-half years after operation The second patient is in only fair health, more than five and one-half years later Extensive studies have revealed spontaneous hypoglycemia and macrocytic anemia as the only significant organic disorders, conditions which do not adequately explain his numerous and bizarre symptoms The diagnosis by a psychiatric consultant is "malignant psychoneurosis", the prognosis is regarded as poor, and institutionalization has been

TABLE 6.—*Patients Living After Total Gastrectomy for Benign Lesions*

Lesion	No. of Patients	Period	Result
Gastric ulcer	1	5 yr 7 mo	Fair
Gastric ulcer	1	4 yr 4 mo	Excellent
Gastric ulcer	1	8 mo	Good
Neurofibroma	1	8 yr 4 mo	Good

recommended The third patient was operated on less than one year ago and appears to be doing well at present

SUMMARY AND CONCLUSIONS

1 Sixty complete gastrectomies have been performed during the past nine years, with 14 deaths, or an operative mortality of 23.3 per cent The lesions for which the operation was performed, with the number of patients, were as follows carcinoma, 53, gastric ulcer, 4, lymphosarcoma, 2, and neurofibroma, 1

2 General peritonitis was the most frequent cause of death, and the most common source of it was leakage at the site of the esophago-jejunal anastomosis

3 Of the 46 patients who survived the operation, 31 have subsequently died In all instances death was due to recurrence of the malignant disease The average duration of life in this group was ten and one-half months

4 Eleven patients are still living after operation for carcinoma Approximately one half of these were operated on too recently for evaluation of the result Three patients may be classified as representing five year cures

5 All the patients with benign lesions who survived operation are living and maintain a satisfactory state of nutrition

6 In 2 patients the classic picture of pernicious anemia developed approximately five years after operation

7 The technical details of the operation are discussed, and the worth of the procedure is considered

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DISCUSSION

DR HOWARD K GRAY, Rochester, Minn When Dr Ransom invited me to open the discussion of this interesting paper, he asked that I review the experience in the Mayo Clinic with removal of the entire stomach. The series begins with the first total gastrectomy performed by Dr W J Mayo, in 1917, and, including the operations performed prior to Jan 1, 1946, comprises 124 cases. The over-all hospital mortality rate for the series was 40.3 per cent. The hospital mortality rate for the 91 cases in which operation was performed in the period from 1940 to 1945, inclusive, was 33.0 per cent, and that for 1945, during which total gastrectomy was performed in 24 cases, was 16.6 per cent (4 deaths). It is interesting to observe the consistency of the over-all hospital mortality rates for the various large series of cases, as recorded in Dr Ransom's paper, and to note the obvious fact that with experience and improvements in preoperative and post-operative care the mortality rate can, and has been, reduced appreciably.

It is widely accepted that the lesion which most often requires complete gastrectomy is carcinoma or lymphoblastoma involving the greater part of the stomach, in particular, the diffuse, "leather bottle" type of carcinoma, or *linitis plastica*. The statement, however, that smaller malignant neoplasms situated in the upper half or the upper third of the stomach are best treated with total gastrectomy is subject to question, for lesions in these areas occasionally lend themselves admirably to removal by the transthoracic route. The procedure does not impose any greater risk than total gastrectomy if performed by a surgeon familiar with both thoracic and gastric surgery. In fact, in the four year period from 1942 to 1945, inclusive, partial gastrectomy was performed at the Mayo Clinic in 29 cases, with 6 deaths in the hospital, a hospital mortality rate of 20.6 per cent.

The argument may be advanced that the transthoracic operations were done primarily for lesions involving the lower part of the esophagus, and secondarily the stomach, and that therefore the transthoracic approach was the only method indicated in these cases. As a matter of fact, in all 29 cases the roentgenologist interpreted the lesion as being located in the upper portion of the stomach and involving the cardia alone in 14 cases, the fundus in 4 cases and the cardia and the lower portion of the esophagus in only 11 cases. In 2 cases in which the lesion was situated in the cardia microscopic examination revealed a benign gastric ulcer, and in 1 case, a leiomyoma. In all 11 cases in which the roentgenologist observed encroachment on the esophagus the pathologist reported that the central ulcerative growth was located in the stomach and was diagnosed as adenocarcinoma, this would be presumptive evidence that the neoplastic lesion had originated in the stomach, with secondary infiltration into the esophagus. That a portion of the stomach may be preserved and normal esophagogastric continuity maintained are added factors in favor of transthoracic approach in selected cases.

A second argument against the transthoracic removal of a malignant lesion of the stomach is that adequate excision of lymph-node-bearing tissue is not possible with this method. Although retrograde involvement of lymph nodes occurs occasionally, it is not common, and, although the time elapsed since the first transthoracic resection has been insufficient to permit definite conclusions regarding the anticipated survival of these unfortunate patients, preliminary studies on the postoperative course have indicated that the survival rate will be as good as, if not better than, that in cases of total gastrectomy.

The third objection to transthoracic resection of the stomach for carcinoma arises from motor difficulties encountered occasionally incident to section of the vagus nerves in the course of the operation. It has been the experience of workers advocating resection of the vagus nerves for benign ulcerating lesion of the stomach that the atony of the gastric musculature and small bowel, with or without varying degrees of pylorospasm, is transient. A similar condition might be anticipated when the vagus nerves are sectioned in the course of a resection of the upper portion of the stomach with reestablishment of esophagogastric continuity.

As has been noted by practically all observers, disturbance of digestive function following total gastrectomy may be important. In a recent report on a patient who had survived eight years after total gastrectomy, Weir pointed out that the digestive functions of pepsin and hydrochloric acid must be taken over by the pancreatic and intestinal enzymes. Ivy showed that in gastrectomized animals the intake of meat may cause diarrhea and that increased amounts of meat, milk and bread are required to maintain normal weight. This observation is consistent with the clinical investigations of Wollaeger, Comfort, Weir and Osterberg (*Proc Central Soc Clin Research* 18:37, 1945), who showed in a study of intake and excretion recently made at the clinic on patients after partial gastrectomy that the loss of fat in the stool was above normal and of variable amount, and that the loss of nitrogen was occasionally increased. The secretion of hydrochloric acid aids in the absorption of calcium and iron. One would expect calcium metabolism to be disturbed in a patient who has undergone total gastrectomy. In Weir's patient there was no disturbance in calcium metabolism, as evidenced by absence of osteoporosis and by the normal content of calcium and phosphorus in the serum. Perhaps the most consistent complaint has been the inability to take more than small quantities of food and the occurrence of the "dumping syndrome," first described by Hertz. Patients with this disorder usually complain immediately after eating of nausea, weakness, pallor, palpitation, tachycardia, perspiration, lightheadedness and faintness. Although the cause of these symptoms is not readily apparent, they are probably due to a reflex effect of too great and too rapid distention of the jejunum by the ingested food. Total removal of the stomach would be presumed to produce a pronounced effect on hematopoiesis because of failure of elaboration of the intrinsic factor, and numerous reports have appeared of the development of pernicious anemia or pernicious-anemia-like syndromes after total gastrectomy.

It was interesting to note in Weir's case that only at the last examination of the patient was there any significant macrocytosis. Slight glossitis occurred at times, but it was only at this examination that any atrophy of the tongue was noted.

RECENT ADVANCES IN VASCULAR SURGERY

A Review of the Literature

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IN THE wake of every great war, notable advances appear in certain scientific fields. It was on the field of battle that Pare revived and developed the use of the ligature in the treatment of arterial injuries. During World War I, clinical and experimental vascular research reached new peaks through the work of Halsted and his pupils, Holman and Reid, and through the work of Matas, Makins, Sehrt, Tuffier, Key and many others. Similarly, in the past few years, enormous strides have been made in vascular surgery.

VASCULAR REPAIR

Blakemore, Lord and Stefko,¹ in their search for a nonsuture technic, modified the old Payr magnesium rings used for vascular anastomosis by the preparation of a vein graft with the ends of the vessel everted over vitallium tubes. Such a cylinder, lined by endothelium and with rigid ends, was designed to be inserted into the proximal and distal ends of an artery in which there is an aneurysm or a loss of continuity owing to injury. Although its use in the armed forces was on a smaller scale than anticipated, this technic of vein grafting has proved of value in selected cases. The main objection to the use of this technic has been occlusion by thrombosis. The projection of the lips of the tubes into the arterial lumen produces eddies in the blood flow, and this, together with the ballooning of the vein when it is subjected to arterial pressure, permits the formation of a clot. Controlled use of heparin and dicumarol

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¹ Blakemore, A. H., Lord, J. W., Jr., and Stefko, P. L. The Severed Primary Artery in the War Wounded. A Nonsuture Method of Bridging Arterial Defects, *Surgery* **12** 488-508 (Sept.) 1942, Restoration in Blood Flow in Damaged Arteries. Further Studies on a Nonsuture Method of Blood Vessel Anastomosis, *Ann. Surg.* **117** 481-497 (April) 1943. Blakemore, A. H., and Lord, J. W., Jr. A Nonsuture Method of Blood Vessel Anastomosis. Experimental and Clinical Study, *J. A. M. A.* **127** 685-691 (March 24) 1945. A Nonsuture Method of Blood Vessel Anastomosis. Experimental and Clinical Study, *ibid* **127** 748-753 (March 31) 1945. A Nonsuture Method of Blood Vessel Anastomosis. Review of Experimental Study, Report of Clinical Cases, *Ann. Surg.* **121** 435-452 (April) 1945.

has reduced this source of criticism. It is conceivable that in large medical centers dealing with many instances of acute trauma, banks of preserved and refrigerated vein grafts may be of value. Recently, Mustard² reported on experiences with nonsuture methods in military units operating near the front lines. He indicated a preference for a plastic rigid tube rather than the vein graft, especially in cases in which a long defect in the artery had to be bridged. Clotting was prevented by administration of dicumarol. Smith³ has employed caramelized dextrose plugs of a diameter slightly greater than the lumen of an artery to be anastomosed end to end. With the ends of the vessel approximated over this cylindric dilator, the task of suturing is said to be easier and any constriction is avoided.

THROMBOEMBOLISM

During the past few years, the most satisfactory method of treating venous thrombosis has been the subject of some disagreement. The outstanding proponents have alined themselves in three main camps. Ochsner and DeBakey⁴ have perhaps led in enthusiasm for sympathetic block, as they have been convinced that the resulting vasodilatation prevents reflex vasospasm and the formation of an embolus. Unquestionably, considerable symptomatic relief is afforded by this procedure. A. W. Allen, Linton and Donaldson,⁵ Homans,⁶ and Linton⁷ have championed ligation of the vein proximal to the thrombotic process. A number of cases in which even the inferior vena cava has been ligated in an effort to prevent pulmonary embolism have been reported by Atlas,⁸ Buxton and others,⁹ Collins and associates,¹⁰ Gaston and Fol-

2 Mustard, W. T. The Technic of Immediate Restoration of Vascular Continuity After Arterial Wounds. Indications and Results, *Ann Surg* **124** 46-59 (July) 1946

3 Smith, S. A Soluble Rod as an Aid to Vascular Anastomosis. An Experimental Study, *Arch Surg* **41** 1004-1007 (Oct) 1940, Studies in Experimental Vascular Surgery, *Surgery* **18** 627-643 (Nov) 1945

4 Ochsner, A., and DeBakey, M. Therapy of Phlebothrombosis and Thrombophlebitis, *Arch Surg* **40** 208-231 (Feb) 1940, Intravenous Clotting and Its Sequelae, *Surgery* **14** 679-690 (Nov) 1943

5 Allen, A. W., Linton, R. R., and Donaldson, G. A. Thrombosis and Embolism. Review of Two Hundred and Two Patients Treated by Femoral Vein Interruption, *Ann Surg* **118** 728-740 (Oct) 1943

6 Homans, J. Deep Quiet Venous Thrombosis in Lower Limb. Preferred Levels for Interruption of Veins, Iliac Sector or Ligation, *Surg, Gynec & Obst.* **79** 70-82 (July) 1944

7 Linton, R. R. Venous Interruption in Thrombo-Embolic Disease, editorial, *Surgery* **19** 434-436 (March) 1946

8 Atlas, L. N. Ligation of the Inferior Vena Cava. A Case Report, *Ohio State M J* **39** 917-918 (Oct) 1943

som,¹¹ Homans,⁶ Kern and Berman,¹² Northway and Buxton,¹³ and O'Neil,¹⁴ and Moses¹⁵ among others Thrombectomy has been performed, in addition, in some cases Still another method of treatment in which anticoagulant drugs are employed has been described by Barker and others,¹⁶ Evans,¹⁷ and de Takats and Fowler¹⁸ Prophylactic and therapeutic use of dicumarol, with the dose controlled by daily determination of the prothrombin time, has proved successful at the Mayo Clinic

As a result of the efficacy of dicumarol, when preceded by the administration of heparin,¹⁹ and antispasmodic drugs, embolectomy rarely is necessary in embolism of a peripheral artery The operation, when done, now is more successful than it was before these anticoagulant drugs were available as an adjunct Wetherell²⁰ has outlined a three phase treatment of arterial embolism which embodies a practical approach to the condition Papaverine is first given and the site of the embolus localized The administration of heparin and dicumarol is begun, and if the vaso-

9 Buxton, R W , Farris, J M , Moyer, C. A , and Coller, F A Surgical Treatment of Long-Standing Deep Phlebitis of the Leg A Preliminary Report, *Surgery* **15**:749-756 (May) 1944

10 Collins, C G , Jones, J R , and Nelson, E W Surgical Treatment of Pelvic Thrombophlebitis Ligation of Inferior Vena Cava and Ovarian Veins, Preliminary Report, *New Orleans M & S J* **95** 324-329 (Jan) 1943

11 Gaston, E A , and Folsom, H Ligation of the Inferior Vena Cava for the Prevention of Pulmonary Embolism A Report of Two Cases, *New England J Med* **233** 229-233 (Aug 23) 1945

12 Kern, H M , and Berman, E Ligation of Inferior Vena Cava for Pneumonic Thrombophlebitis, *Am J Surg* **69** 120-125 (July) 1945

13 Northway, R O , and Buxton, R W Ligation of the Inferior Vena Cava, *Surgery* **18** 85-94 (July) 1945

14 O'Neil, E E Ligation of the Inferior Vena Cava in the Prevention and Treatment of Pulmonary Embolism, *New England J Med* **232** 641-646 (May 31) 1945

15 Moses, W R Ligation of the Inferior Vena Cava or Iliac Veins A Report of Thirty-Six Operations, *New England J Med* **235** 1-7 (July 4) 1946

16 Barker, N W , Cromer, H E , Hurn, M , and Waugh, J M The Use of Dicumarol in the Prevention of Postoperative Thrombosis and Embolism with Special Reference to Dosage and Safe Administration, *Surgery* **17** 207-217 (Feb) 1945

17 Barker, N W Anticoagulant Therapy in Postoperative Thrombophlebitis and Pulmonary Embolism, *Minnesota Med* **29** 778-782 (Aug) 1946

18 Evans, J A The Combined Use of Heparin and Dicoumarin (3,3' Methyl-enebis, 4-Hydroxycoumarin) in Thrombophlebitis and Pulmonary Embolism Preliminary Report, *Lake Clin Bull* **2** 248-256 (April) 1942

19 de Takats, G , and Fowler, E F The Problem of Thrombo Embolism *Surgery* **17** 153-177 (Feb) 1945

20 Murray, G H Heparin in Surgical Treatment of Blood Vessels, *Arch Surg* **40** 307-325 (Feb) 1940

21 Wetherell, F S Treatment of Arterial Embolism of the Extremities A Three-Phase Division, *New York State J Med* **44** 35-42 (Jan 1) 1944

spasm has not been broken in one to two hours paravertebral block of the lumbar sympathetic ganglions is carried out. If this is not successful, embolectomy is performed with local anesthesia.

COLLATERAL CIRCULATION

In obstructive lesions of the vascular system such as those due to arterial disease, embolism, thrombosis, tumor or ligature, the integrity of the part depends on the efficiency of the collateral circulation. In 1933, Gage²¹ introduced the use of sympathetic block to stimulate the formation of a collateral circulation and to avoid vasospasm in cases of aneurysm. Subsequently, sympathectomy has been used more successfully for this purpose. Up to the time of the recent war, there was considerable controversy as to the actual value of this procedure in cases of chronic arteriovenous fistula, which in itself was believed to be the greatest known stimulus to collateral circulation. Within the past two years there have been a number of reports by Linton and White,²² Pugh,²³ Harbison,²⁴ Kirtley,²⁵ and Mason and Giddings²⁶ which indicate that sympathectomy has a definite beneficial influence in such cases, as it prevents vasospasm, increases the collateral circulation and lessens the danger of anaerobic infection. Recently, Deterling, Essex and Waugh²⁷ demonstrated experimentally on dogs, by arteriography and determination of the cutaneous temperature, that while arterial collateral circulation appears rapidly in cases of femoral arteriovenous fistula it may be further stimulated, even after six months or more, by sympathectomy. With such a procedure available, it may be possible to effect an early closure of such fistulas, thus avoiding the local and general

21 Gage, M. Mycotic Aneurysm of the Common Iliac Artery. Sympathetic Ganglion Block as an Aid in the Development of the Collateral Circulation in Arterial Aneurysm of Peripheral Arteries, Report of a Case, *Tr South S A* **46** 473-516, 1933.

22 Linton, R R, and White, P D. Arteriovenous Fistula Between the Right Common Iliac Artery and the Inferior Vena Cava. Report of a Case of Its Occurrence Following an Operation for a Ruptured Intervertebral Disk with Cure by Operation, *Arch Surg* **50** 6-13 (Jan) 1945.

23 Pugh, H L. Surgical Management of Vascular Trauma, *Am J Surg* **68** 5-20 (April) 1945.

24 Harbison, S P. Experiences with Aneurysms in an Overseas General Hospital, *Surg, Gynec & Obst* **81** 128-137 (Aug) 1945.

25 Kirtley, J A. Arterial Injuries in a Theatre of Operations, *Ann Surg* **122** 223-234 (Aug) 1945.

26 Mason, J M, III, and Giddings, W P. Experience with Lumbar Sympathetic Ganglionectomy for Wounds of Major Blood Vessels of the Lower Extremity, *Surg, Gynec & Obst* **81** 169-176 (Aug) 1945.

27 Deterling, R. A., Jr., Essex, H E, and Waugh, J M. Arteriovenous Fistula. Experimental Study of the Influence of the Sympathetic Nervous System on the Development of Collateral Circulation, *Surg, Gynec & Obst* **84** 629-641 (April) 1947.

cardiovascular alterations which develop in time in the presence of such a lesion²⁸

ANEURYSM

Simple arterial aneurysms have been treated by a variety of chemical, mechanical and surgical procedures. Blakemore and King²⁹ have had success with an improved technic of electrothermic coagulation in cases of aortic aneurysm. In certain cases of peripheral aneurysm Blakemore has used an inlay vein graft and his vitallium tube nonsuture technic³⁰. With the aneurysmal sac opened, the ends of the prepared venous segment are inserted into the arterial ostium, and the wall of the sac imbricated over the graft to lend support. Mention should be made of the increasing use of permeable "cellophane" and other films to effect gradual closure of a vessel by virtue of the stenosing fibrosis evoked. This action on living tissues was demonstrated in 1939 by Page³¹ when he obtained a pronounced fibrosis of the renal capsule following the application of "cellophane" to the kidneys in an experimental study of hypertension. Pearse³² in 1940 extended its use to the vascular system by a series of experiments on the aortas of dogs. Subsequently, "cellophane" has been used to aid in the obliteration of the ductus arteriosus. Harrison and Chandy³³ reported the cure of a subclavian aneurysm by the occlusive action of such fibrosis. "Cellophane" bands had been placed about the vessel on either side of the aneurysmal sac. Poppe and de Oliveira³⁴ described the degree of reactivity of tissue to the various types of films which induce fibrosis and reported the successful application of polythene to a fusiform aneurysm of the thoracic aorta.

PORTAL HYPERTENSION

As a result of the excellent work of the spleen clinic at the Columbia-Presbyterian Medical Center in New York, there has been a greater

28 Mason, J M. Extreme Cardiac Decompensation Following Traumatic Arteriovenous Fistula of the Left Subclavian Vessels, *Am J Surg* **20** 451-473 (May) 1933. Mason, J M., Graham, G S., and Bush J D. Early Cardiac Decompensation in Traumatic Arteriovenous Aneurysm, *Ann Surg* **107** 1029-1036 (June) 1938.

29 Blakemore, A H., and King, B G. Electrothermic Coagulation of Aortic Aneurysms, *J A M A* **111** 1821-1827 (Nov 12) 1938.

30 Blakemore, A H. Personal communication to the author.

31 Page, I H. A Method for Producing Persistent Hypertension by Cellophane, *Science* **89** 273-274 (March 24) 1939.

32 Pearse, H E. Experimental Studies on the Gradual Occlusion of Large Arteries, *Ann Surg* **112** 923-933 (Nov) 1940.

33 Harrison, P W., and Chandy, J. A Subclavian Aneurysm Cured by Cellophane Fibrosis, *Ann Surg* **118** 478-481 (Sept.) 1943.

34 Poppe, J K., and de Oliveira, H R. Treatment of Syphilitic Aneurysms by Cellophane Wrapping, *J Thoracic Surg* **15** 185-195 (June) 1946.

understanding of portal hypertension Whipple's group has divided cases of portal hypertension into two groups (1) cases of intrahepatic block, in which the obstruction is in the liver, and (2) cases of extrahepatic block, in which the obstruction is in the portal vein or one of its tributaries³⁵ As a result of surgical experience, Blakemore and Lord³⁶ have demonstrated that the latter type of lesion is more amenable to operative intervention In some cases there is congenital atresia of the portal vein or cavernous transformation, while thrombotic obstruction secondary to trauma or infection is present in other cases The diagnosis generally is established by the presence of splenomegaly, anemia, leukopenia and thrombopenia and a history of hemorrhages from the stomach and the intestinal tract When present, normal hepatic function will help distinguish extrahepatic block from intrahepatic block At operation, the exact site of the obstruction is determined by direct examination or, in some cases, by the difference of venous pressures in the coronary, superior mesenteric and splenic veins If the portal vein cannot be utilized, as in some cases of congenital lesions, an end to end splenorenal venous anastomosis may be employed This shunting of portal blood into the systemic veins necessitates sacrifice of the spleen and left kidney and serves to shunt only 30 per cent or so of the portal blood Consequently, in cases in which the portal pressure is two and a half to five times as great as it normally is (the normal pressure is 10 cm of water), an end to side portacaval anastomosis may produce a swift regression of symptoms As a result of successful experiments, it has been proposed that in cases in which such an increase in portal pressure is associated with massive ascites (usually cases of intrahepatic block) the proximal open end of the left ureter remaining after a splenorenal anastomosis should be sutured into the peritoneal space, thus offering a conduit for the ascitic fluid to drain by way of the bladder

CONGENITAL CARDIOVASCULAR ANOMALIES

In the realm of thoracic surgery, the successful operative cure of certain congenital lesions of the heart and great vessels has been one of the outstanding achievements in medical science Although there has not been any significant work on intracardiac surgery for valvular stenosis since the efforts of Cushing, Bernheim, Carrel, Graham and Cutler and their co-workers,³⁷ the war has made the heart a surgical organ The literature contains reports of many cases in which

35 Whipple, A O The Problem of Portal Hypertension in Relation to the Hepatosplenopathies, Ann Surg **122** 449-475 (Oct.) 1945, Rationale of Portacaval Anastomosis, Bull New York Acad Med **22** 251-253 (May) 1946

36 Blakemore, A H, and Lord, J W, Jr The Technic of Using Vitallium Tubes in Establishing Portacaval Shunts for Portal Hypertension, Ann Surg **122** 476-489 (Oct) 1945 Blakemore, A H Portacaval Anastomosis Report on Fourteen Cases, Bull New York Acad Med **22** 254-263 (May) 1946.

missiles have been removed successfully from the walls or chambers of the heart³⁸ The recent introduction of an improved cardioscope by Harken and Glidden³⁹ once again widens the possible scope of surgical treatment

Congenital malformations of the cardiovascular system often are associated with other anomalies, such as arachnodactyly, mongolism, spina bifida and cleft palate, which may serve in themselves to warn the physician to look for a lesion of the heart Congenital cardiac defects are said to comprise 2 per cent of all cardiac lesions that become evident before the age of 12 years The incidence of lesions of the aorta such as the presence of bicuspid valves and hypoplasia, coarctation and stenosis, is greater among males than it is among females, while the incidence of patent ductus arteriosus is greater among females

At the meeting of the Minnesota State Medical Association in June 1947, R E Gross presented an interesting series of cases in which tracheal or esophageal obstruction was observed in infants as a result of anomalies of the aortic arch and its major branches The compression in these instances resulted from the presence of a double aortic arch, from the innominate artery which originated adjacent to the left common carotid artery, or from an anomalous right subclavian artery which originated distal to the left subclavian artery Symptomatic relief was accomplished by division of the anomalous vessel, or by displacement

37 Cushing, H, and Branch, J R B Experimental and Clinical Notes on Chronic Valvular Lesions in the Dog and Their Possible Relation to a Future Surgery of the Cardiac Valves, *J M Research* **17** 471-486 (Feb) 1908 Bernheim, B M Experimental Surgery of the Mitral Valve, *Bull Johns Hopkins Hosp* **20** 107-110 (April) 1909 Carrel, A, and Tuffier, T Etude anatomo-pathologique et expérimentale sur la chirurgie des orifices du cœur, *Presse med* **1** 173-177 (March 4) 1914 Allen, D S, and Graham, E A Intracardiac Surgery A New Method, Preliminary Report, *J A M A* **79** 1028-1030 (Sept 23) 1922 Graham, E A Recent Phases of Thoracic Surgery, *ibid* **80** 1825-1831 (June 23) 1923 Cutler, E C, Levine, S A, and Beck, C S The Surgical Treatment of Mitral Stenosis Experimental and Clinical Studies, *Arch Surg* **9** 689-821 (Nov) 1924 Cutler, E C, and Beck, C S The Present Status of the Surgical Procedures in Chronic Valvular Disease of the Heart Final Report of All Surgical Cases, *ibid* **18** 403-416 (Jan) 1929

38 Harken, D E Foreign Bodies In, and in Relation to, the Thoracic Blood Vessels and Heart I Techniques for Approaching and Removing Foreign Bodies from the Chambers of the Heart, *Surg, Gynec & Obst* **83** 117-125 (July) 1946 Harken, D E, and Williams, A C Foreign Bodies in and in Relation to the Thoracic Blood Vessels and Heart Migratory Foreign Bodies Within the Blood Vascular System, *Am J Surg* **72** 80-90 (July) 1946 Harken, D E, and Zoll P M Foreign Bodies in and in Relation to the Thoracic Blood Vessels and Heart III Indications for the Removal of Intracardiac Foreign Bodies and the Behavior of the Heart During Manipulation *Am Heart J* **32** 1-19 (July) 1941 Shapiro, R Intracardiac Foreign Body Report of a Case with Recovery *ibid* **30** 88-91 (July) 1945

39 Harken, D E, and Glidden E M Experiments in Intracardiac Surgery II Intracardiac Visualization, I Thoracic Surg **12** 566-572 (Aug) 1943

of the vessel by fixation to adjacent structures when division of the vessel appeared hazardous

Patent Ductus Arteriosus—The ductus arteriosus serves a necessary function in the fetal circulation in joining the systemic and pulmonary circuits. Although originally noted by Galen,⁴⁰ it has been known as the ductus Botalli since its description by Botallus⁴¹ in 1660. After birth, the channel undergoes involution as a result of physiologic and anatomic alterations associated with normal pulmonary function. Kennedy⁴² in a study on guinea pigs and Barclay, Bancroft, Barron and Franklin⁴³ by the use of arteriography of fetal lambs delivered by cesarean section showed that functional closure of the ductus arteriosus may occur in as short a time as five minutes after birth. The anatomic closure is a slower process, but normally the tract has become a fibrous cord by the third week of extrauterine life. However, the vessel occasionally continues to persist. Christie⁴⁴ stated that while only 35 per cent of these vessels are closed by two weeks, only 1 per cent are patent after one year. Abbott⁴⁵ found 242 cases of patent ductus arteriosus in 1,000 cases of congenital heart disease. In these 1,000 cases, the incidence of patent ductus arteriosus was second only to that of intracardiac septal defects. As a result of the experimental work by Eppinger, Burwell and Gross,⁴⁶ considerable knowledge has been gained as to the disturbance of cardiovascular function in cases of patent ductus arteriosus. From studies on oxygen content of the whole blood, these authors showed that the direction of blood flow is typically from the aorta into the pulmonary artery, as described by Rokitansky⁴⁷ in 1852. Clinical evidence to support their work is the usual absence of cyanosis, aortic pressure being higher than the pulmonary pressure, the dilatation of the pulmonary artery, and the fact that vegetations in subacute bacterial endarteritis are most frequent on the pulmonary side of the

40 Galen, cited by Gilchrist.⁵⁰

41 Botallus, L. *Opera omnia, medica et chirurgica*, Lugd Batavia, Joannis van Horne, 1660, p. 66.

42 Kennedy J A. A New Concept of the Cause of Patency of the Ductus Arteriosus, *Am J M Sc.* **204**: 570-573 (Oct) 1942.

43 Barclay, A E, Barcroft, J, Barron, D H, and Franklin, K J. A Radiographic Demonstration of the Circulation Through the Heart in the Adult and in the Foetus, and the Identification of the Ductus Arteriosus, *Brit J Radiol* **12**: 505-517 (Sept.) 1939.

44 Christie, A. Normal Closing Time of the Foramen Ovale and the Ductus Arteriosus. An Anatomic and Statistical Study, *Am. J Dis Child.* **40**: 323-326 (Aug) 1930.

45 Abbott, M E. *Atlas of Congenital Cardiac Disease*, New York, American Heart Association, 1936.

46 Eppinger, E C, Burwell, C S, and Gross, R E. The Effects of the Patent Ductus Arteriosus on the Circulation, *J Clin Investigation* **20**: 127-143 (March) 1941.

47 Rokitansky, cited by Holman.⁴⁸

ductus arteriosus. Some cases have been reported in which there was a reversed direction of blood flow, frequently a result of an associated congenital defect.⁴⁸ Although a patent ductus arteriosus represents an arteriovenous shunt, the effect on cardiac output differs from that of peripheral arteriovenous fistulas. In cases of the latter anomaly, there is as much as 100 per cent increase in the output of both ventricles. In the presence of ductus arteriosus, the output of the left ventricle may increase 75 per cent, but there is an associated decrease in that of the right ventricle.⁴⁹ However, a wide pulse pressure is found in both types of shunt, as is an increase in the total volume of circulating blood.

Certain diagnosis of patent ductus arteriosus is not always easy,⁵⁰ although it has been stated that in 70 per cent of the cases the diagnosis is made by the time the patients are 20 years of age.⁵⁰ There is often a history of "heart trouble" and poor development from early childhood, with an absence of cyanosis or clubbing of the digits. Examination should reveal a roaring machinery murmur with a frequent associated thrill, first described by Gibson⁵¹ in 1898. The systolic phase of the murmur is generally accentuated, as is the pulmonic second sound. The area of greatest intensity of the murmur is in the second intercostal space to the left of the sternum. The murmur may be transmitted to the vessels of the neck. A narrow ductus arteriosus produces a high-pitched loud murmur, while with a wide ductus arteriosus there may be no murmur or a murmur of low intensity. Gerhardt's sign, a band of dulness to percussion along the left sternal border in the first, second and third interspaces, is rarely noted. Although the heart may be somewhat enlarged, especially the left auricle and ventricle, the electrocardiogram is generally normal. Stunting of growth and underdevelopment are the result of the shunting of a large proportion of the output of the left ventricle into the pulmonary circuit instead of into the peripheral systemic circulation. Roentgenographic examination often will reveal dilatation of the pulmonary artery and roentgenoscopy may disclose excessive hilar pulsation.⁵²

Closure of this abnormal communication is the indicated treatment unless a marked degree of hypoplasia or stenosis of either great vessel is present. In such cases, a patent ductus arteriosus serves as a collateral.

48 Holman, E. Certain Types of Congenital Heart Disease Interpreted as Intracardiac Arteriovenous and Venocardial Fistulae. Bull Johns Hopkins Hosp 36: 61-80 (Jan) 1925.

49 Shapiro, M. J. Patent Ductus Arteriosus. Journal-Lancet 64: 137-139 (Mar) 1944.

50 Gilchrist, A. R. Patent Ductus Arteriosus and Its Surgical Treatment. Brit Heart J 7: 1-36 (Jan) 1945.

51 Gibson, cited by Gilchrist.⁵⁰

52 Huben, M. I. Roentgen Diagnosis of Patent Ductus Arteriosus with Report of a Case Complicated by Presence of Saccular Aneurysm. Am J Roentgenol 7: 23-26 (Jan) 1920.

circulation Ordinarily, however, severe complications result from such a communication It has been estimated that from 25 to 30 per cent of patients who have this anomaly die of cardiac failure and that subacute bacterial endarteritis develops in 30 to 40 per cent of cases The life expectancy has been said to be 25 to 35 years Bullock and his associates,⁵³ reviewed 80 fatal cases and found that 14 per cent of the patients were dead by 15 years of age, 50 per cent were dead at the age of 30 years and 71 per cent were dead at 40 years Even though the newer antibiotics are effective in treatment of endarteritis, the continued decline in morbidity and mortality in cases in which operation is performed makes this the treatment of choice

Before the assembly of the Philadelphia Academy of Surgery in 1907, Munro⁵⁴ proposed surgical closure of the ductus arteriosus, but it was not to be attempted until thirty years later, when Strieder unsuccessfully operated in a case in which subacute bacterial endarteritis⁵⁵ was present On Aug 26, 1938, Gross⁵⁶ closed a ductus arteriosus successfully by ligation in continuity, a feat which was repeated shortly afterward in many parts of the world It was not until 1940 that Touroff and Vesell⁵⁷ reported the successful ligation of a ductus arteriosus in the presence of endarteritis Closure of the ductus has been effective in curing subacute bacterial endarteritis⁵⁸ The operative technic has passed through various evolutions as recurrences were reported after simple ligation⁵⁹ Gross⁶⁰ found the use of "cellophane" bands to

53 Bullock, L T , Jones, J C , and Dolley, F S The Diagnosis and the Effects of Ligation of the Patent Ductus Arteriosus A Report of Eleven Cases, J Pediat. **15** 786-801 (Dec) 1939

54 Munro, J C I Ligation of the Ductus Arteriosus, Ann Surg **46** 335-338 (Sept) 1907

55 Graybiel, A , Strieder, J W , and Boyer, N H An Attempt to Obliterate the Patent Ductus Arteriosus in a Patient with Subacute Bacterial Endarteritis, Am Heart J **15** 621-624 (May) 1938

56 Gross, R E , and Hubbard, J P Surgical Ligation of a Patent Ductus Arteriosus Report of First Successful Case, J A M A **112** 729-731 (Feb 25) 1939

57 Touroff, A S W , and Vesell, H Subacute Streptococcus Viridans Endarteritis Complicating Patent Ductus Arteriosus Recovery Following Surgical Treatment, J A M A **115** 1270-1272 (Oct. 12) 1940

58 Tubbs, O S The Effect of Ligation on Infection of the Patent Ductus Arteriosus, Brit J Surg **32** 1-12 (July) 1944

59 Gross, R E A Surgical Approach for Ligation of a Patent Ductus Arteriosus, New England J Med **220** 510-514 (March 23) 1939, Surgical Management of the Patent Ductus Arteriosus with Summary of Four Surgically Treated Cases, Ann Surg **110** 321-351 (Sept) 1939, Surgical Therapy for the Patent Ductus Arteriosus, New York State J Med **43** 1856-1858 (Oct. 1) 1943

60 Gross, R E Complete Surgical Division of the Patent Ductus Arteriosus A Report of Fourteen Successful Cases, Surg , Gynec & Obst. **78** 36-43 (Jan) 1944

stimulate a fibrous stricture rather successful. Involvement of the recurrent laryngeal nerve by the fibrotic process has not proved to be a complication. Harper and Robinson⁶¹ reported an interesting case in which "cellophane" was used in addition to the ligation. In this case, a recurrence of the lesion was cured by the fibrosis which developed as a result of the action of the "cellophane". Blalock⁶² has isolated the vessel by transfixion sutures at each end and has successfully obliterated the channel by a cotton tape ligature. Since ligation and division of a vessel are to be preferred in vascular surgery to ligation in continuity, occlusion by modified Crile clamps, division of the vessel and a continuous suture of its ends have been advocated by Gross⁶⁰ as the most dependable means of preventing a recurrence. Up to July 1947 he had performed this procedure in 177 cases with but 4 deaths. None of these was due to hemorrhage. However, if the tissue is friable and if endarteritis has occurred recently, the operative risk of this procedure is high in most hands. Crafoord⁶³ has even clamped off the aorta during division and suturing of the ductus. Since penicillin has become available, the mortality rate associated with closure of an uncomplicated ductus arteriosus should be well under 5 per cent and no higher than 10 per cent in cases in which subacute bacterial endarteritis is present. Before this drug was available, it was noted that closure of the ductus served to cure the endarteritis in many instances. The optimal time for operation is in childhood, since adults are more likely to have less cardiac reserve and frequently have an extremely short ductus, which makes the operation more hazardous.

Coarctation of the Aorta—Coarctation of the aorta was described as a clinical entity by Paris⁶⁴ in 1791. Subsequently, Bonnet⁶⁵ divided this anomaly into two types (1) infantile and (2) adult. The former type is found in infants who have died of the stenosis within the first year of life. In this type, the atresia or constriction is diffuse and involves a large portion of the thoracic aorta. Severe associated anomalies frequently are present and, since the collateral channels are insufficient, death is inevitable. The adult type, which I shall consider, results from a congenital annular stenosis of the thoracic aorta at or near the entrance of the ductus arteriosus. In about 10 per cent of

61 Harper, F. R., and Robinson, M. E. Occlusion of Infected Patent Ductus Arteriosus with Cellophane, *Am. J. Surg.* **64**: 294-296 (Mar.) 1944.

62 Blalock, A. Operative Closure of the Patent Ductus Arteriosus, *Surg. Gynec. & Obst.* **82**: 113-114 (Feb.) 1946.

63 Crafoord, C., and Nylin, G. Congenital Coarctation of Aorta and Its Surgical Treatment, *J. Thoracic Surg.* **14**: 347-361 (Oct.) 1945.

64 Paris. Retracissement considérable de l'aorte pectorale. *J. de chir.* **2**: 107-110, 1791.

65 Bonnet, cited by Blumenthal and Davis.⁶⁶

cases, one finds the ductus arteriosus patent⁶⁶ The aortic obstruction may serve to impede the natural process of involution

Authors have disagreed regarding the incidence of the adult type of coarctation. In a study of 1,000 cases of congenital defects of the heart, Abbott⁶⁵ found 142 cases of coarctation of the aorta. In 105 of the 142 cases, the coarctation was of the adult type. Fawcett⁶⁷ reported that 18 instances of coarctation were found in 22,316 cases in which necropsy was performed at Guy's Hospital in the years 1826 to 1902. Blackford⁶⁸ reported that 44 instances of this anomaly were disclosed by 68,300 necropsies, a ratio of approximately 1 to 1,550. Evans⁶⁹ found that the incidence of both infantile and adult forms of this anomaly was 0.13 per cent in a series of 19,217 cases in which necropsy was performed. The adult type occurred in a ratio of 1 case to 1,471 necropsies. Perlman⁷⁰ analyzed the results of routine medical examination of a large number of selectees for military service and found only 1 instance of coarctation among every 10,000 men who were 18 to 35 years of age.

It should be noted, however, that Abbott⁷¹ found that the diagnosis of coarctation had not been made clinically in 86 per cent of a series of 200 cases, and King⁷² in 1926 said that a clinical diagnosis of this anomaly had been made only four times in thirty-seven years at Johns Hopkins Hospital. In the past two decades, however, the clinical diagnosis has been made with increasing frequency⁷³. Levine⁷⁴ has

66 Abbott, M. E. Statistical Study and Historical Retrospect of Two Hundred Recorded Cases, with Autopsy, of Stenosis or Obliteration of the Descending Arch, *Am Heart J* **3** 392-421 (April) 1928

67 Fawcett, J. Coarctation of the Aorta as Illustrated by Cases from the Post-Mortem Records of Guy's Hospital from 1826-1902, *Guy's Hosp Rep* **44** 1-19, 1905

68 Blackford, L. M. Coarctation of the Aorta, *Arch Int Med* **41** 702-735 (May) 1928

69 Evans, W. Congenital Stenosis (Coarctation), Atresia, and Interruption of the Aortic Arch. A Study of Twenty-Eight Cases, *Quart J Med* **2** 1-32 (Jan) 1933

70 Perlman, L. Coarctation of the Aorta. Clinical and Roentgenologic Analysis of Thirteen Cases, *Am Heart J* **28** 24-38 (July) 1944

71 Abbott, M. E. Coarctation of the Aorta of the Adult Type II. A Statistical Study and Historical Retrospect of Two Hundred Recorded Cases with Autopsy, of Stenosis or Obliteration of the Descending Arch in Subjects Above the Age of Two Years, *Am Heart J* **3** 574-618 (June) 1928, footnote 66

72 King, J. T., Jr. Stenosis of the Isthmus (Coarctation) of the Aorta and Its Diagnosis During Life. Report of Four Cases, *Arch Int Med* **38** 69-95 (July) 1926

73 Rhodes, P. H., and Durbin, E. Coarctation of the Aorta in Childhood. Review of the Literature and Report of Three Cases, *Am J Dis Child* **64** 1073-1096 (Dec) 1942

74 Levine, S. A. *Clinical Heart Disease*, Philadelphia, W. B. Saunders Company, 1940

estimated that 0.1 per cent of the entire population has some degree of coarctation. Contrary to simple patent ductus arteriosus, coarctation is observed in males more frequently than it is in females, the ratio of males to females being about 4 to 1. It is interesting to note from Abbott's analysis that in 75 per cent of 200 cases the patients were males, they had an aortic lumen of less than 6 mm at the site of coarctation, they died before the age of 40 years and they died of the coarctation or its direct cardiovascular complications.⁶⁶

The alterations in cardiovascular function in cases of coarctation are significant and interesting. The early development of collateral channels often permits the patients to carry on more strenuous activities than would be anticipated from the degree of obstruction. Since the site of the coarctation is below the origin of the left subclavian artery in almost all cases, the accessory circulation is derived largely from anastomoses of (1) the superior intercostal with the first aortic intercostal artery, (2) the internal mammary with the epigastric and intercostal arteries and (3) the subscapular with the circumflex scapular artery. The position of the obstruction causes major changes in the dynamics of the circulation above and below.

The increase in the amount of blood that flows through the vessels of the upper extremities, the neck and the head is evidenced in some cases by an elevation of the basal metabolic rate. Grollman and Ferrigan⁷⁵ expressed the opinion that this is due to increased blood supply to the thyroid gland. Because of the redistribution of blood around a centrally situated block, the peripheral flow of blood may be greater than normal. An elevation in cutaneous temperature of the lower part of the body, as well as an elevation of rectal temperature, has been recorded by Stewart and his co-workers,⁷⁶ but unpublished studies performed in Roth's laboratory at the Mayo Clinic failed to confirm these findings. The effect of coarctation on renal function has been studied by many investigators, since the cause of the attendant hypertension has been attributed to either renal ischemia or simple mechanical obstruction. This has been perhaps the most disputed aspect of the condition. Friedman and his associates,⁷⁷ in 1941 byulin and "diodrast" clearance studies found that the blood supply of the kidney was definitely decreased. They explained the normal rate of glomerular filtration on the basis of increased filtration pressure secondary to spasm of the efferent arterioles. This supported the results of an experimental study

75 Grollman, A., and Ferrigan, J. P. Jr. Cardiac Output Its Related Functions in a Case of Coarctation of the Aorta Arch Int Med 53: 35-38 (Jan) 1934

76 Stewart, H. J., Haskell, H. S., and Evans, W. F. The Peripheral Blood Flow and Other Observations in Coarctation of the Aorta Am Heart J 28: 217-232 (Aug) 1944

77 Friedman, M., Selzer, A., and Rosenblum, H. The Renal Blood Flow in Coarctation of the Aorta J Clin Investigation 20: 107-111 (March) 1941

on rats by Rytand⁷⁸, namely, that renal hypertension may be caused by the ischemia Woodbury and associates,⁷⁹ Steele,⁸⁰ Stewart and co-workers,⁸¹ and others have pointed out that the narrow pulse pressure and high diastolic pressure in the lower extremities indicate a widespread arteriolar spasm and increased peripheral resistance compatible with renal hypertension Microscopic examination of specimens of skin obtained from the arm and the leg of a patient, aged 34 years, who had coarctation and severe hypertension and who was observed at the Mayo Clinic, revealed severe hyperplasia of the walls of the arterioles, which was of a greater degree in the vessels of the leg than it was in the vessels of the arm, however, Graybiel and his associates⁸² were unable to demonstrate such alterations in a group of 5 young patients who had mild hypertension Blumgart and his co-workers⁸³ found a normal arteriolar pressure in the arms of 2 patients and suggested that hypertension was the result of the mechanical effects of the stenosis and the relatively small caliber of the collateral channels Brotchner⁸⁴ reported 5 clinical cases and performed occlusion experiments on the aortas of animals to support the mechanical theory rather than the pressor theory This problem seems closer to a solution as a result of the satisfactory drop in blood pressure seen in most cases after operative removal of the coarctation Although the apparent role of the mechanical block has been elucidated, it must be remembered that most of the patients who have been operated on have been young Perhaps the renal factor becomes increasingly important as the patient grows older In the first case of coarctation in which resection was performed at the Mayo Clinic, the patient was a man, aged 34 years,

78 Rytand, D A The Renal Factor in Arterial Hypertension with Coarctation of the Aorta, *J Clin Investigation* **17** 391-399 (July) 1938, Pathogenesis of Arterial Hypertension in Coarctation of Aorta, *Proc Soc. Exper Biol & Med* **38** 10-11 (Feb) 1938

79 Woodbury, R. A., Murphey, E. E., and Hamilton, W. F. Blood Pressures in Aortic Coarctation Study of Pulse Contours Taken by the Direct Method, *Arch Int Med.* **65** 752-762 (April) 1940

80 Steele, J. M. Evidence for General Distribution of Peripheral Resistance in Coarctation of the Aorta Report of Three Cases, *J Clin Investigation* **20** 473-480 (Sept.) 1941

81 Stewart, H. J., and Bailey, R. L., Jr. The Cardiac Output and Other Measurements of the Circulation in Coarctation of the Aorta, *J Clin Investigation* **20** 145-152 (March) 1941

82 Graybiel, A., Allen, A. W., and White, P. D. Histological Study of Arterioles of Muscle and Skin from Arm and Leg in Individuals with Coarctation of Aorta, *J Clin Investigation* **14** 52-56 (Jan) 1935

83 Blumgart, H. L., Lawrence, J. S., and Ernstene, A. C. The Dynamics of the Circulation in Coarctation (Stenosis of the Isthmus) of the Aorta of the Adult Type Relation to Essential Hypertension, *Arch Int. Med.* **47** 806-823 (May) 1931

84 Brotchner, R. J. Etiology of Hypertension Resulting from Coarctation of the Aorta, *Arch Path* **28** 676-696 (Nov) 1939

whose diastolic pressure remained higher than 90 mm of mercury for a few weeks after operation His systolic and diastolic pressures then declined, and six months after operation his brachial arterial pressure was within normal limits Gross followed the pressures in 20 cases in which resection had been carried out, and noted satisfactory decrease in all but 1 In this case the anastomosis left a smaller lumen than desired He noted that the decrease in blood pressure generally does not occur for ten to twelve days after operation

It has been shown that while the circulation time is usually normal above the site of obstruction, there is a definite slowing distally Cardiac output has been measured by Grollman and Ferrigan⁷⁵ (1934), Stewart and Bailey⁸¹ (1941) and others This has been found normal or only slightly increased when the heart was well compensated As about 25 per cent of the deaths are due to cardiac decompensation, this must be ruled out in such studies The electrocardiogram, while usually normal, will show a left axis deviation as the commonest abnormality A negative T wave in lead III frequently is seen, with or without coving (Stewart and Bailey⁸¹) The characteristic changes of essential hypertension also are found

The presence of this condition should be suspected in any youth who has hypertension and pronounced pulsation of the carotid arteries Many patients will have signs of aortic regurgitation Between 25 and 40 per cent of patients coming to necropsy have bicuspid aortic valves The greatly dilated and tortuous intercostal arteries, first illustrated by Meckel⁸⁵ in 1827, may become evident by their pulsation and bruit Occasionally, the vessels may be felt over the scapular region As the degree of stenosis increases, the strength of the pulsations in the femoral arteries decreases until, in cases of marked occlusion, no distal pulses can be felt Dock⁸⁶ emphasized the lag in femoral pulse behind the radial pulse and advised simultaneous palpation of the femoral and radial arteries Auscultation of the thorax frequently will reveal a harsh blowing systolic murmur, which is heard best in the posterior interscapular area and is independent of the diastolic aortic precordial murmur heard when aortic insufficiency is present

A number of significant roentgenologic signs of coarctation have been described⁸⁷ Primary or direct signs are (1) the absence of the aortic knob, normally visualized to the left of the fifth thoracic vertebra on a posteroanterior roentgenogram, and (2) a defect of 1 to 2 cm in the aortic shadow as outlined in a left oblique roentgenogram Secon-

⁸⁵ Meckel cited by Abbott⁴

⁸⁶ Dock W The Recognition of Coarctation of the Aorta J A M A 99 2024-2025 (Dec 10) 1932

⁸⁷ Perlman⁷⁶ Ernstene, A C and Robins S A The Roentgenologic Diagnosis of Stenosis of the Descending Arch (Coarctation) of the Aorta Am J Roentgenol 25 243-246 (Feb) 1931 Frazee W W The Roentgenologic Diagnosis of Coarctation of the Aorta (Adult Type), Am J Radiol 24 349-352 (Oct) 1931

dary or indirect signs are hypertrophy of the left ventricle (found in 75 per cent of the cases in Abbott's series⁶⁶), dilatation of the ascending aorta and aortic arch proximal to the lesion (noted in 50 per cent of the cases in Abbott's series) and evidence of erosion of the ribs. The scalloping of the under surface of the ribs due to pressure erosion of the bone by the varicose intercostal vessels has been designated "Rösler's sign"⁸⁸ or "Dock's sign"⁸⁹

The reasons for considering surgical resection of the coarctation and primary anastomosis of the aorta are many. The life expectancy is estimated to be 36 years. Death occurs from the effects of the coarctation in 77 per cent of cases, and in about the same percentage of cases death occurs before the age of 40 years. About 30 per cent of the patients die of decompensation and aortic insufficiency, 25 per cent die of rupture of the aorta and the remainder die of cerebral hemorrhage, sudden asystole, subacute bacterial endarteritis and rupture of an aneurysm, usually just proximal to the coarctation. The incidence of arteriosclerosis has been reported to be high in cases of coarctation.

As for indications for operation, one must consider the ability of the patient to withstand total occlusion of the aorta during the surgical procedure. Consequently, if the degree of coarctation is marked, the aorta may be occluded safely by virtue of the great collateral circulation. In complete atresia in which the entire aortic flow is diverted into other vessels, there is theoretically no time limit to the repair since no further obstruction results from clamping the aorta. In the 200 cases reported by Abbott,⁶⁶ complete atresia was present in 25 per cent, and narrowing to less than 6 mm was present in an additional 50 per cent. Such patients should have little or no pulse or pressure in the femoral arteries. The severer the coarctation, the greater is the indication for operation. The optimal age for operation has been considered to be between 8 and 25 years.

The successful repair of this anomaly is truly a milestone in surgery and was the direct result of experimental and clinical research since 1938 by Gross⁹⁰ and Blalock⁹¹ in America and Crafoord⁶³ in

88 Rösler, H. Beiträge zur Lehre von den angeborenen Herzfehlern IV. Untersuchungen an zwei Fällen von Isthmusstenose der Aorta, Wien Arch f inn. Med. **15** 521-546, 1928

89 Railback, O. C., and Dock, W. Erosion of the Ribs Due to Stenosis of the Isthmus (Coarctation) of the Aorta, Radiology **12** 58-61 (Jan.) 1929

90 Gross, R. E., and Hufnagel, C. A. Coarctation of Aorta Experimental Studies Regarding Its Surgical Correction, New England J Med **233** 287-293 (Sept. 6) 1945

91 Blalock, A., and Park, E. A. The Surgical Treatment of Experimental Coarctation (Atresia) of the Aorta, Ann Surg **119** 445-456 (March) 1944 Levy S. E., and Blalock, A. Experimental Observations on the Effects of Connecting by Suture the Left Main Pulmonary Artery to the Systemic Circulation, J Thoracic Surg **8** 525-530 (June) 1939

Sweden In December 1944 Alexander⁹² successfully performed thoracic aortectomy at the site of coarctation and aneurysm, but vascular continuity was not reestablished. In September 1945 Gross and Hufnagel⁹⁰ reported their experimental work and briefly mentioned 2 cases in which operation had been performed. In the first case, the patient unfortunately died of acute cardiac dilatation. Subsequently, Gross described these patients in greater detail⁹³ and has elucidated the surgical technic.⁹⁴ Crafoord and Nylin,⁶³ in October 1945, reported 2 cases in which resection and primary anastomosis were performed successfully by the Carrel technic. Up to February 1947, Crafoord had carried out resection in 15 cases of coarctation with 2 deaths. Up to July 1947, Gross had done resection in 22 cases, with but 2 deaths. Blalock, Clagett and others have now performed the operation successfully. Clagett has had occasion to anastomose the dilated left subclavian artery to the aorta distal to the stenosis in several cases, with or without resection of the coarctation.⁹⁵ Experimental work on various modifications of the technic is being carried out in many medical centers at the present time. As may be claimed in the case of surgical repair of a patent ductus arteriosus, a successful early operation in a case of uncomplicated coarctation may restore the patient to normal.

Pulmonary Stenosis or Atresia.—Stenosis or atresia of the pulmonary artery is another congenital anomaly which recently has been treated surgically. This anomaly was present in 205 of the 1,000 cases of congenital heart disease reported by Abbott.⁴⁵ When the anomaly is associated with a closed interventricular septum, there frequently is little cyanosis. However, there are relatively few cases without an interventricular septal defect. Atresia and stenosis of the pulmonary artery without septal defect each was present in about 10 per cent of the cases reported by Abbott. The remaining cases generally were classified as cases of the tetralogy of Fallot, that is, pulmonary stenosis, dextroposition of the aorta, defect of the interventricular septum and hypertrophy of the right ventricle. Although a simple defect of the ventricular septum (*maladie de Roger*) is a relatively common congenital defect and can be tolerated well, its association with hypoplasia of the pulmonary artery results in a serious clinical syndrome. Instead of the blood's flowing through the defect

92 Alexander J and Byron F V. Aortectomy for Thoracic Aneurysm. *J A M A* **126**: 1139-1145 (Dec 30) 1944.

93 Gross R E. Surgical Correction for Correction of the Aorta. *Surgery* **18**: 673-678 (Dec) 1945.

94 Gross, R E. Technical Considerations in Surgical Therapy for Coarctation of the Aorta. *Surgery* **20**: 1-8 (July) 1946.

95 Crafoord C. Personal communication to the author. Chester O T. Correction of the Aorta. Surgical Aspects. Proc Staff Meet Mayo Clin **22**: 131-135 (April 2) 1947.

from the left ventricle to the right ventricle, the stenosis obstructs the pulmonary circulation sufficiently to reverse the direction of the flow in the ventricles. Aeration of the resultant small amount of circulating blood in the pulmonary circuit is not sufficient to prevent cyanosis.

The condition should be suspected if a child has clubbing of the digits, severe cyanosis and dyspnea on exertion. The physical examination of the thorax usually will reveal a harsh systolic murmur at the second to fourth intercostal spaces at the left border of the sternum. A vibrant thrill can be felt in about 30 per cent of cases. There is severe polycythemia. The value for the hemoglobin may become 26 Gm per hundred cubic centimeters of blood and the erythrocyte count may be as high as 10,000,000 per cubic millimeter of blood. The electrocardiogram reveals a pronounced right axis deviation.

The surgical treatment of stenosis or atresia of the pulmonary artery has been primarily directed toward augmenting the flow of blood through the lungs and hence increasing the oxygenation of the circulating hemoglobin. Babcock⁹⁶ (1932) performed an end to end caroticojugular arteriovenous anastomosis in 1 case. The operation was performed to increase (1) the velocity of blood through the heart, (2) the cardiac output and return and (3) the degree of oxygen saturation of the hemoglobin in the pulmonary artery. It was hoped that a more frequent passage of blood with an elevated initial oxygen saturation through the lung would improve the condition. Unfortunately, the presence of widespread pulmonary tuberculosis in the patient obviated any hope for improvement.

On the basis of experimental work which showed the plausibility of anastomosis of systemic arteries to one of the pulmonary arteries, Blalock⁹⁷ (1945) devised an operation to increase the volume of blood which flows through the pulmonary circuit. In cases of atresia and stenosis, this is accomplished by an end to side anastomosis of the innominate or subclavian artery to the pulmonary artery. This in essence produces an artificial ductus arteriosus. This fact constitutes one of the chief objections to the operation, as one cardiovascular abnormality actually is substituted for another. The child may be subject to the complications of the ductus arteriosus, possibly with less ability to withstand the physiologic disturbances.

In cases of untreated pulmonary stenosis, the life expectancy is only 12½ years, with a maximum of about 25 years. Chief complications are cardiac failure, poor development and thrombosis. Operation aims

96 Babcock, W. W. Newer Surgical Methods of Treating Diseases of the Vascular System, Am J Surg 16: 401-407 (June) 1932.

97 Blalock, A., and Taussig, H. B. The Surgical Treatment of Malformations of the Heart in Which There Is Pulmonary Stenosis or Pulmonary Atresia, J A M A. 128: 189-202 (May 19) 1945.

primarily at increasing the pulmonary blood flow and, consequently, the oxygenation of the hemoglobin. The presence of 5 Gm of reduced hemoglobin is sufficient to cause cyanosis. It has been notable that in cases in which operation has been performed, there has been a rapid fall in concentration of hemoglobin and in the erythrocyte count, with regression of the cyanosis. Blalock, since his first report in May 1945, has performed the operation in several hundred cases with good results. By now, many other surgeons have successfully performed the operation. With penicillin therapy available for the treatment of subacute bacterial endarteritis, and with the improvement in treatment of cardiac failure, it is probable that a substantial extension of more normal life has been attained for children who have been operated on for atresia or stenosis of the pulmonary artery.

NEW AND IMPROVED DIAGNOSTIC PROCEDURES

The exact diagnosis of congenital lesions of the heart and other vascular disorders has been advanced in the past several years by rapid developments in the field of arteriography and angiocardiography. In the early thirties these diagnostic procedures were mainly of academic interest because of the crude technics and the use of rather toxic concentrations of sodium iodide and colloidal thorium dioxide. However, with relatively innocuous contrast mediums now available for visualization of the heart and great vessels, a number of workers have developed safe technics.

Notable contributions to the visualization of the chambers of the heart and the great vessels have been those of Perez de los Reyes, Castellanos and Pereiras⁹⁸ and Robb and Steinberg⁹⁹. The abdominal aorta and its branches have been studied by Farinás¹⁰⁰. The accurate identification

98 Perez de los Reyes, R., Castellanos, A. and Pereiras R. Angiocardiography and Its Value, Am Heart J 25: 298-306 (March) 1943

99 Robb G P, and Steinberg, I. Visualization of the Chambers of the Heart, the Pulmonary Circulation, and the Great Blood Vessels in Man, Am J Roentgenol 41: 1-17 (Jan) 1939, A Practical Method of Visualization of the Chambers of the Heart, the Pulmonary Circulation and the Great Blood Vessels in Man, J Clin Investigation 17: 507 (May 2) 1938, Visualization of the Chambers of the Heart, the Pulmonary Circulation, and the Great Blood Vessels in Heart Disease Preliminary Observations Am J Roentgenol 42: 14-36 (July) 1939, Visualization of the Chambers of the Heart and the Thoracic Blood Vessels in Pulmonary Heart Disease A Case Study, Ann Int Med 13: 12-45 (July) 1939, Visualization of the Chambers of the Heart, the Pulmonary Circulation and the Great Blood Vessels in Man Summary of Method and Results I & II M A 114: 474-480 (Feb 10) 1940

100 Farinás, P L. A New Technique for the Arteriographic Examination of the Abdominal Aorta and Its Branches Am J Roentgenol 46: 641-645 (Nov) 1941, Retrograde Arteriography in the Study of the Abdominal Aorta and Its Major Arteries, Surgery 18: 244-249 (Aug) 1945, Retrograde Abdominal Arteriography Am J Roentgenol 55: 448-451 (April) 1946

of aneurysm, defects of the cardiac septum, coarctation of the aorta, tetralogy of Fallot and other congenital anomalies have been described recently by Robb and Steinberg,¹⁰⁰ Steinberg and associates,¹⁰¹ Grishman and co-workers,¹⁰² Sussman and co-workers,¹⁰³ Pérez de los Reyes and others,¹⁰⁴ Thompson,¹⁰⁴ Olney and Miller,¹⁰⁵ Stewart and associates,¹⁰⁶ Blumenthal and Davis¹⁰⁷ and others. Some of the contrast mediums that have been used for this purpose are "parabrodil," "iopax," "neoiopax," "hippuran" N N R and "diodrast" N N R. This last substance used in concentrations of 70 per cent has been most successful in the hands of American workers. The use of single roentgenograms timed for passage of the medium through the pulmonary circuit and through the left side of the heart and the aorta has been improved by the use of rapid multiple exposures (Sussman and his associates¹⁰³) or cineroentgenography by which the course of the medium from the time of its injection may be followed continuously on the roentgenoscopic screen and photographed with the cinecamera (Stewart and his co-workers¹⁰⁶). Electrocardiography and catheterization of the chambers of the heart and great vessels have added much information as to the physiologic alterations resulting from these cardiovascular anomalies. As knowledge of congenital disorders is increased by such studies, one may expect the surgical treatment of cardiovascular disorders to continue to advance.

101 Steinberg, I., Robb, G. P., and Roche, U. J. Differential Diagnosis of Mediastinal Tumor and Aortic Aneurysm. Value of Contrast Cardiovascular Visualization, *New York State J Med* **40** 1168-1177 (Aug 1) 1940.

102 Grishman, A., Steinberg, M. F., and Sussman, M. L. Tetralogy of Fallot. Contrast Visualization of Heart and Great Vessels, *Radiology* **87** 178-180 (Aug) 1941, Contrast Roentgen Visualization of Coarctation of the Aorta, *Am Heart J* **21** 365-370 (March) 1941.

103 Sussman, M. L., Grishman, A., and Steinberg, M. F. Newer Concepts in the Diagnosis of Congenital Heart Disease, *Am J Dis Child* **65** 922-936 (June) 1943.

104 Thompson, S. A. Differential Diagnosis by Means of Intravenous Contrast Medium of Two Cases Simulating Aneurysm of the Pulmonary Artery, *Am J Roentgenol* **46** 646-649 (Nov) 1941.

105 Olney, M. B., and Miller, E. R. Use of Intravenous Cardiography in the Study of Congenital Heart Disease with Cyanosis, *Clinics* **3** 235-244 (June) 1944.

106 Stewart, W. H., Breimer, C. W., and Maier, H. C. Cineroentgenographic Diagnosis of Congenital and Acquired Heart Disease, *Am J Roentgenol* **46** 636-640 (Nov) 1941.

107 Blumenthal, S., and Davis, D. B. Coarctation of the Aorta in Childhood. Report of Two Cases in Which the Diagnosis Was Confirmed by the Intravenous Injection of Diodrast, *Am J Dis Child* **62** 1224-1232 (Dec) 1941.

OSTEOTOMY IN TREATMENT OF FRACTURES OF THE HIP

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MOST surgeons concede that the average case of intracapsular fracture of the neck of the femur still represents a major, and often irretrievable, disaster. Internal fixation of the fresh fracture and various methods of restoration of stability in cases with nonunion have been great advances. The younger group of patients, unfortunately small, usually does well, but, in all fairness, one must admit a high percentage of bad results in the run of cases. The causes of failure in the treatment of fresh fractures of the neck of the femur are well known, they include (1) inadequate reduction and pinning, (2) degenerated bony structure which in the aged will not support internal fixation, (3) late aseptic necrosis (or fragmentation) of the head of the femur, (4) degenerative arthritis, with or without bony union, and (5) too early weight bearing on a bad mechanical line subject to shearing force.

A recent personal poll of thirty leading orthopedic surgeons showed that there is still a wide divergence of opinion regarding the handling of both fresh and old fractures of the neck of the femur. With the omission of all cases but those of one year survival, the percentage in which bony union was obtained ranged from 60 to 90. As expected, some of the lower percentages were obtained among derelicts by surgeons working on charity services of large city hospitals. On the other hand, Henderson,¹ Meyerding¹ and Ghormley,² of the Mayo Clinic, reported bony union in 80 to 90 per cent of cases, modestly ascribing their high percentage of success to the fact that their patients of this type were largely vigorous farm folk living within 50 to 100 miles (8 to 16 kilometers) of Rochester, Minn. I hope that the reader bears in mind that I work in a large city, for my percentage of cases with satisfactory bony union is not more than 65.

Whatever the cause, all the surgeons questioned had seen many bad results in cases of intracapsular fracture of the neck of the femur. Practically all stated that they use some form of reconstruction operation generally the Colonna or Brackett type, at least with the younger or more vigorous subjects reserving osteotomy for the older group. This personal survey, as well as the literature of the past few years shows

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¹ Personal communication to the author 1946.

that an increasing number of the leading surgeons of England and America perform osteotomy for all old fractures of the hip to correct bad results, whether due to malunion, nonunion or degenerative arthritis. Frank Dickson,¹ Leadbetter,² Wallace Cole,¹ Kellogg Speed,³ J S Speed (Memphis),⁴ George Bennett,¹ Hermann,⁵ Barney Owen,¹ and McMurray,⁶ of England, are a few who now use osteotomy as the treatment of choice in cases of old ununited fracture. Reich⁷ and Magnuson⁸ have used osteotomy with excellent results. Cole¹ and Murphy⁹ have employed this method instead of primary pinning, while McMurray⁶ uses it exclusively with both fresh and old intracapsular fractures. A few, though not the majority, reported the use of pins to hold the fragments after osteotomy. High osteotomy is more popular because of the greater chance of bony union in the original fracture and because internal fixation of the fragments is almost obligatory with the Schanz, or low, osteotomy.

All of the well known reconstruction operations of the hip were great contributions. Diagrammatically all can be made to look simple and efficient. In actual practice others, as well as myself, have found it necessary to use these procedures only in selected cases, because of conditions present at the site of fracture or because of the condition of the patient. Such procedures as the bone peg operation or the Brackett, Whitman or Colonna reconstruction are all formidable as to risk and are difficult of execution. J S Speed stated that only about 60 per cent of fairly good results are obtained with these large procedures even in selected cases and that 25 per cent of the favorable results are later vitiated by degenerative arthritis, causing painful and restricted movement of the hip. Against the net 45 per cent of satisfactory results from reconstruction operations performed only on patients who are good

2 Leadbetter, G W Cervical-Axial Osteotomy of the Femur Preliminary Report, *J Bone & Joint Surg* **26** 713-720 (Oct) 1944

3 Speed, K. Treatment of Postoperative Infections Following Internal Fixation for Fracture of the Neck of the Femur, *Tr West. S. A.* **52** 567-582, 1945, Subtrochanteric Osteotomy for Ununited Fracture of the Neck of the Femur, *Ann Surg* **124** 576-585 (Sept.) 1946

4 Speed, J S, and Smith, H Trochanteric Osteotomy for Ununited Fractures of the Neck of the Femur, *South M J* **34** 798-806 (Aug) 1941

5 Hermann, O J The McMurray Osteotomy for Nonunited Hip Fractures, *New England J Med.* **232** 186-189 (Feb 15) 1945

6 McMurray, T P Ununited Fractures of the Neck of the Femur, *J Bone & Joint Surg* **18** 319-327 (April) 1936

7 Reich, R S Ununited Fracture of the Neck of the Femur Treated by High Oblique Osteotomy, *J Bone & Joint Surg* **23** 141-158 (Jan.) 1941

8 Magnuson, P R. Fractures (Modified Brackett), Philadelphia, J B Lippincott Company, 1933

9 Murphy, F G Subtrochanteric Osteotomy for Fresh Fracture of the Neck of the Femur, *S Clin North America* **23** 211-220 (Feb) 1943

risks, most men reported about 80 per cent of good results with osteotomy as used on all types of patients, and bony union was achieved in about half, 50 per cent. The only procedure showing comparable results is the rarely indicated bone peg operation.

The advantages of osteotomy, presented so ably before this society by Kellogg Speed, are as follows:

- 1 It is a simple procedure, suitable to practically all age groups.
- 2 Aseptic necrosis of the head of the femur and degenerative arthritis have not been contraindications.
- 3 A good weight-bearing line, without shearing force, with or without bony union is achieved. Properly executed, a strong, stable hip is the probable result in the average case.
- 4 Revascularization of the head of the femur which has already undergone partial aseptic necrosis is not unusual.
- 5 About 80 per cent of good results can be expected, with bony union in at least 50 per cent. With proper technic, the percentage of bony union can be improved.
- 6 Few late degenerative changes have been noted after successful osteotomy.
- 7 Normal leverage of the gluteal and psoas muscles is preserved, making for stability of the hip.
- 8 Osteotomy is useful in treatment of malum coxae semilis.
- 9 The period of immobilization and non-weight-bearing is short. Objections to the spica cast are minimized by active muscular exercises and proper general management while the patient is in the cast. Henderson still uses a spica cast after internal fixation of fresh fractures. I agree with Dickson, Henderson and others, who feel that the disadvantages of casts are overrated. The rigid, twisted, hyperextended leg in the Whitman cast often caused stiffness of joints. After osteotomy the leg is in the neutral position with the knee slightly bent, and the cast is worn for only eight weeks.

TECHNIC OF OSTEOTOMY

During the past few years many fine discussions on high osteotomy have appeared in the literature. In each instance, the technic of the operation is dismissed with the statement that a high osteotomy at the proper point was made, followed by inward displacement of the shaft of the femur. It is true that the procedure is simple and a fair number of good results can be obtained with even a poorly performed osteotomy. Through a study of the factors involved in several poor results a personally satisfactory technic has been evolved. On the other hand important points have been discovered accidentally by observing the reasons for unusually successful results in 2 cases.

Before operation, roentgenograms are made on the operating table with the leg under manual traction. The line of osteotomy is then determined. A point as near as possible to the base of the greater trochanter is selected which will still allow the line of osteotomy to pass upward and inward to a level through or above the lesser trochanter. The higher the line of osteotomy can be made, the broader the base of the cancellous bone that can be obtained and the better the rotation of the head. Thus, more of the old fracture line can be freshened and brought into contact with the lower osteotomy fragment. To prevent knock knee, a certain amount of obliquity in the osteotomy is necessary to allow about 20 degrees of abduction and still have contact of the shaft with all three fragments. The greater the obliquity of the osteotomy, the more abduction is required for solid contact. Since not more than 20 degrees of abduction is desirable, the direction of the osteotome must be carefully guided. The high osteotomy with a certain amount of obliquity provides a broad base of cancellous, very highly osteogenic, bone at the upper end of the shaft. Proof of the reparative quality of bone in this area is shown by the fact that nonunion of intertrochanteric fractures is unknown. Before osteotomy is done, the periosteum must be stripped from the whole circumference of the upper end of the shaft through a vertical incision below the greater trochanter. The periosteum should be stripped clear for 3 or 4 inches (7.5 or 10 cm) down on the shaft and as high as possible toward the trochanter and neck. The sheet of periosteum must be kept intact anteriorly and posteriorly. This maneuver is one of the critical points in performing successful osteotomy, because after the bone is cut through and the shaft displaced inwardly the periosteal connections between the shaft and the severed trochanter allow the trochanter also to be drawn snugly against the head and better contact against the shaft is also maintained. The three fragments can now be manually impacted in the desired position. Union is more assured, and internal fixation with pins to prevent separation of fragments is obviated. After the periosteum is separated and retracted anteriorly and posteriorly, osteotomy is performed on the predetermined line, using an osteotome slightly narrower than the shaft. The osteotome cuts through the periosteum on the medial aspect. At times it may be difficult to preserve both the anterior and the posterior periosteal strip, but any retained connection is valuable. An attempt is now made to rotate the head of the femur with a blunt elevator so that the old fractured surface faces somewhat downward. The shaft is now displaced inward, using the osteotome as a combination lever and shoehorn. Often the upper inner point of the shaft, impinging against the lower edge of the head of the femur, can be made to aid in further rotating the head, so that more of the old fracture line can be brought into contact with the shaft. In this way union is more apt to be obtained, more new bone is deposited in the line of weight bearing, and the head is in a better position to receive weight bearing should bony union not be achieved. The portion of the head lying directly above the displaced shaft and as much of its old fractured surface as possible are now freshened with the osteotome, and pieces of bone from the osteotomized margins of the trochanter and shaft are forced into or around the old fracture area. Before closure of the wound, a roentgenogram is made to be sure the shaft has been displaced sufficiently inward and the inner margin impacted solidly against and beneath the lower margin of the head.

A double spica cast to the toes of the affected leg and the knee of the good leg is applied. The body portion of the cast need embrace only the pelvic region and can be cut down in front to a point below the level of the navel. After soreness from the operation has subsided, the patient is taught to contract actively all

muscle groups systematically, exercising five minutes of each waking hour. At the end of six weeks the cast is bivalved and more vigorous exercises are permitted. The entire cast is removed at the end of eight weeks, and after a few more days of exercises in bed the patient is started in a walker or on crutches, with gradually increasing weight bearing. From this point progress will vary with each patient, but all are encouraged to abandon walking aids as soon as possible.

COMMENT ON PERSONAL CASES

This report is based on the following personal experience: (1) osteotomy for old intracapsular fractures of the hip, 19 cases; (2) osteotomy for fresh intracapsular fractures, 2 cases, on which it is too early to report, and (3) osteotomy for malum coxae senilis without fracture, 4 cases.

A statistical study of these cases would be worthless and misleading. There were a number of bad results among the earlier cases. With a better mechanical and physiologic conception of the problem, the results have been more satisfactory. This series of cases is too small for dogmatic conclusions, but the impression gained is that fairly good restoration of function, usually with bony union, can be expected with osteotomy properly performed.

Malum coxae senilis is a form of degeneration in the head of the femur, probably due to partial loss of blood supply. Observing revascularization in a partially dead head of the femur following osteotomy for nonunion, I decided to try this procedure for malum coxae senilis. The only variation in technic is that the line of osteotomy is slightly more oblique and the inner margin of the shaft is displaced inward, always beneath the lower margin of the acetabulum. One patient has complete relief at the time of this report, four years after operation, the condition of 1 is improved and that of the other 2 is not improved. These results are not spectacular, but the intention is to use the method in a larger series. It must be admitted that my own experience with other operations for this condition have been disappointing. The Australian procedure, consisting of making multiple drill holes through the trochanter into the head to encourage a new blood supply, has not achieved its objective in my hands but it suggested the use of osteotomy.

bearing and the higher percentage of cases of degenerative arthritis are factors arguing against internal fixation. Points in favor of osteotomy are:

1 Complete valgus position and elimination of the shearing angle are achieved.

2 Better vascularization of the head with less danger of late arthritis and septic necrosis can be expected.

3 Osteotomy is technically easier in cases of fresh fractures than in cases of old ones because the shaft can be displaced inward and the head rotated more easily. The line of fracture is more nearly horizontal than vertical, completely eliminating the shearing angle. With the technic previously described, the continuity of periosteum and the pull of the common muscles attached to the osteotomized fragments tend to produce snug apposition of all three fragments without internal fixation.

4 Instead of the twisted, hyperextended position necessary with the old Whitman method, a comfortable cast is applied with the knee slightly bent, and the danger of subsequent stiffness of joints is kept at a minimum.

5 The results so far reported have been good. The average shortening has been about $\frac{1}{2}$ inch (1.27 cm.), and motion of the hip joint, with the exception of full adduction, has been satisfactory. My own cases are too recent for final report, but it is my intention to continue the use of the method.

SUMMARY AND CONCLUSIONS

My technic for osteotomy is described.

Osteotomy seems to be the safest and best procedure for all old fractures of the hip.

There are no contraindications to osteotomy referable to the condition or the position of the fragments.

Osteotomy is useful in many other conditions of the hip, such as malum coxae senilis.

Osteotomy may partially or completely supplant internal fixation in the treatment of fresh intracapsular fractures of the hip.

902 Carew Tower

DISCUSSION

DR KELLOGG SPEED, Chicago: Is the problem of recent or old fracture of the hip solved? As Dr Asbury stated, there are still unsatisfactory results. Here, I hear that good results are obtained in 86 per cent of patients after fracture but that the percentage after ununited fracture is much lower.

Certainly, inadequate reduction at the primary treatment is often at fault. In some instances, complete reduction by manipulation, either with or without skeletal traction and use of a fracture table, cannot be obtained. This failure leads either

to open reduction, which may be undesirable, or to acceptance by the surgeon of a fairly satisfactory incomplete reduction as a compromise.

The other points mentioned in this paper are well taken especially that of late aseptic necrosis of the head of the femur, which may occur proximal to the area of union with the diaphysis, depending on incomplete revascularization of the head, as a result of manipulation or fixation or of too short a period of freedom from primary weight bearing. This late necrosis is an important complication. It may be the result of anoxia of the bone deprived of adequate circulation, aided by mechanical pressure, and comes on up to five years or more after the healing across the fractured plane. Its occurrence is unpredictable during the early course of the healing, even with roentgenologic control from the start.

For that reason, subtrochanteric osteotomy may become the primary treatment of choice. It is a way of sidetracking the pinning procedure and the long convalescence of bony healing without weight bearing. Finally, it is possible that revascularization of the head will be obtained in a higher percentage of cases after osteotomy. Time and trial will tell.

For morbus coxae senilis, with its narrowed and permanently changed painful hip joint, headed by nature toward final stiffening, I prefer to use arthrodesis which does away with pain, leg shortening and axial change and seems to offer adequate support for the relatively few years of life remaining to the average patient.

The problem of fracture still remains unsolved.

TREATMENT OF LOCALIZED INFECTIONS WITH PENICILLIN INFILTRATION

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COLUMBUS, OHIO

THIS report deals with regional infiltration with penicillin, a method of therapy that has demonstrated its value in localized infections.

Florey¹ in his original 15 cases in which treatment was with penicillin suggested the possibilities of local application of penicillin. Fraser² and Flippin³ injected penicillin into the cavities of soft tissue abscesses after aspiration of the purulent exudate. Several writers⁴ have recommended the topical use of penicillin in the form of creams or solutions. Cutler and Sandusky⁵ advocated a combination of penicillin powder and lyophilized human plasma. There are many reports⁶ of the use of penicillin in combination with surgical débridement and its instillation into closed cavities. Peck⁷ presented 15 cases in which penicillin solution was injected directly into the necrotic tissues or

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1 Florey, M E, and Florey, H W General and Local Administration of Penicillin, Lancet **1** 387-397, 1943

2 Fraser, D B Local Treatment of Breast Abscess with Penicillin, Brit. M J **1** 523-524, 1944

3 Flippin, H F Penicillin Therapy, Delaware State M J **17** 17-41, 1945

4 Sophrian, L H, and Connally, V J The Use of Penicillin in Topical Application, Am J M Sc **208** 577-580, 1944 Barron, J N., and Mansfield, O T The Local Application of Penicillin in Soft Tissue Lesions, Brit. M J **1** 521-524, 1944 Roxburgh, I O, Christie, R V, and Roxburgh, A C Penicillin in Treatment of Certain Diseases of the Skin, ibid **1** 524-528, 1944

5 Cutler, E C, and Sandusky, W R A Method for Local Administration of Penicillin, Surgery **16** 937-938, 1944

6 Dawson, M H, and Hobby, G L The Clinical Use of Penicillin Observation in One Hundred Cases, J A M A **124** 611-622 (March 4) 1944 Lockwood, J S, White, W L, and Murphy, F D The Use of Penicillin in Surgical Infections, Ann Surg **120** 311-349, 1944 Robertson, I M Penicillin in Bone Infections, Brit M J **1** 519-521, 1944 Mowlem, R Surgery and Penicillin in Mandibular Infections, ibid **1** 517-519, 1944 Fisher, A M The Therapeutic Value of Penicillin Applied Locally, Based on Experience with the Crude Material in a Variety of Infections, Bull Johns Hopkins Hosp **76** 134-153, 1945

7 Peck, F B Penicillin with Special Reference to Its Use in Infections Complicating Diabetes, Am J M Sc **208** 581-596, 1944

sinuses of infected areas in diabetic patients with good results. He utilized a solution of penicillin in isotonic sodium chloride in a concentration of 100 to 1,000 units per cubic centimeter. These injections were repeated as often as every three hours. Rose and Hurwitz⁸ reported 24 cases in which treatment was by daily injection in three or four sites at the margin of tenderness and toward the center of infection. Their rationale in this approach was an attempt to reinforce the natural barrier against infection set up by the host. Solutions of penicillin in concentrations up to 60,000 units per cubic centimeter were used without difficulty. The results were strikingly good. In the present series of cases localized infections were encompassed by a penicillin solution infiltrated entirely around the lesions, including the base, by means of multiple injections.

The effects of these injections in this series of cases were similar to those recorded by Rose and Hurwitz. The first infiltration was always moderately painful, but the subsequent ones were less so. The amount of pain depended on the care and slowness with which the infiltration was made. Pain from the infection itself disappeared a few minutes after the infiltration was made, however, and the lesion usually remained painless for many hours afterward. When pain did return, it was of less intensity than prior to the treatment. In all cases the erythematous area changed from a fiery to a dull red with a tinge of cyanosis. This cyanosis persisted long after the infection had been eradicated. The area of tenderness rapidly receded, and in cases in which there had been tender regional lymph nodes that tenderness also disappeared.

In a few cases in which pus had already formed and was near the surface, spontaneous evacuation occurred despite treatment. In 1 patient a small incision was made to evacuate the pus. In most instances healing occurred with resorption of pus and resolution of indurated tissues. No toxic reaction or sloughing of tissues was noted. Avoidance of disfiguring scars and of long hospitalization was extremely gratifying. Nevertheless, sound surgical judgment must be exercised in the selection and treatment of these patients.

with penicillin solution at the outer margin of erythema or edema, two or more points of entry being used for the injections. Before the infiltration the area was cleansed with a mercurial antiseptic and 70 per cent alcohol or alcohol alone.

Injections were made once a day. The dose of penicillin as well as the volume of solution was varied according to type, location and size of the involved area. Subsequent injections were made as indicated. As much as 200,000 units of penicillin and as large a volume of solution as 50 cc were used in some of the cases. The rationale for the large doses was the apparent effectiveness of penicillin when massive doses are used even against such nonsusceptible organisms as *Escherichia coli*. As far as possible, treatment was limited to local infiltration.

RESULTS

The present series comprise 12 patients, 6 treated as outpatients and 6 as inpatients. The former group consists of 3 patients with carbuncles and 3 with furuncles, the latter of 2 patients with carbuncles and 4 with cellulitis. The table is a summary of the cases in which treatment was given.

Two of the cases are presented in detail to illustrate the method and the results of such treatment.

REPORT OF CASES

CASE 1—R. M., a 67 year old white woman with a known hypertensive history of ten years, was admitted with an inadequately incised carbuncle on the back of the neck. The patient noted a boil at this site about one week prior to admission. This lesion progressively increased in size and in painfulness.

Physical examination revealed a toxic, somewhat delirious elderly woman with a temperature of 100.8 F, a pulse rate of 66 and a respiratory rate of 30. Blood pressure was 212 systolic and 102 diastolic. On the back of the neck was a large carbuncle measuring 5 by 5 cm with pronounced swelling, erythema and tenderness. In the center of this mass was a small cruciate incision draining seropurulent material. Surrounding this were several small necrotic heads. Occipital nodes were enlarged and tender. As movement was extremely painful, the head was held rigidly in a slightly flexed position.

Laboratory studies revealed a hemoglobin value of 13 Gm, 18,500 white blood cells and normal urine free of sugar.

Penicillin, 30,000 units immediately and 20,000 units every three hours intramuscularly, was given and hot packs were applied over the lesion. After four hours the temperature had risen to 102.6 F (rectally). It was decided to try local infiltration of penicillin. Therefore 100,000 units in 20 cc was used to infiltrate the lesion in its entirety at the outer margin of erythema and induration. There was considerable pain associated with the infiltration in spite of 16 mg of morphine given one-half hour before the procedure. However, shortly after the infiltration the pain was gone. The following day she no longer had any pain from the carbuncle. The lesion was a dull, cyanotic red, and the area of tenderness had diminished slightly. This method of treatment was continued daily for eleven days.

Year of Cases in Which There Was Treatment of Localized Infections with Penicillin Infiltration

Plaster cast	Associated Disease	Units per Volume Cc	No. of Treatments	Frequency of Treatment	Total Units	Other Treatment	Results
1 infantile neck	Hypertension	10,000	20	Daily	11	110,000	Complete resolution and healing
1 infantile neck	Sensitivity bronchitis, cholangitis, fecal and urinary incontinence	10,000	40	Daily	11	2,200,000	Healing with hot pack.
1 infantile right arm	Lymphadenitis	10,000	12	Daily	3	16,000	None
1 infantile multiple & chronic	Lymphadenitis	10,000	9	Daily	4	100,000	None
1 infantile multiple & chronic	Lymphadenitis	10,000	10	Daily	2	20,000	Healed
1 infantile right with fistula	Lymphadenitis	10,000	10	Daily	2	20,000	Healed with spontaneous drainage
1 infantile leg	None	20,000	10	Daily	6	720,000 (1000 hot day)	Healing without graft attempt at graft site failed
1 infantile neck	None	10,000	9	Daily	1	10,000	None
1 infantile neck	None	10,000	2	Daily	2	20,000	None
1 infantile neck	None	10,000	2	Daily	2	20,000	None
1 infantile neck	None	10,000	1	Daily	1	10,000	None
1 infantile neck	None	10,000	10	Daily	2	200,000	None
1 infantile neck	None	10,000	2	Daily	1	17,000	None
1 infantile neck	None	10,000	1	Daily	1	10,000	Healed

as were the intramuscular administration of penicillin and the application of hot packs. In all, 2,870,000 units of penicillin was given, of this 1,100,000 units was used locally and 1,770,000 units intramuscularly.

By the third day her temperature had dropped to less than 100 F and her white blood cell count to 7,200. She was feeling much better and eating well. The carbuncle rapidly resolved without discharging the necrotic tissue but by resorption of this material. At the time of discharge, fourteen days after admission, the lesion had completely healed, leaving an 8 mm scar. The skin at the site of the carbuncle was still cyanotic. There was considerable residual induration of the subcutaneous tissues in this area. Three weeks after her discharge she was seen in the outpatient department. The examining physician stated that the cyanosis and some induration were still present, but that there was no evidence of infection or tenderness in the area.

This was the first case in which regional infiltration was attempted. In spite of the fact that penicillin had also been used intramuscularly, the apparent beneficial effects of the local infiltration encouraged its trial in further cases without parenteral administration of penicillin.

CASE 7—T. E., a 42 year old female hospital employee, presented herself to the emergency room with a sore on the back of her neck, which she had noted three to four days previously. This lesion had gradually grown worse.

Physical examination revealed a well developed woman with a temperature of 97.8 F, pulse rate of 84 and a respiratory rate of 20. On the back of her neck was a carbuncle with several heads. The erythematous area measured 3 cm in diameter. Induration involved an area about 4 to 5 cm in diameter. It was tender and painful out to the margin of induration. There was a small draining sinus in the center of the lesion. No nodes were felt.

Local infiltration with 20 cc of solution containing 100,000 units of penicillin was made at the outer margin of erythema. The patient suffered a moderate amount of pain. Some fluid was forced from the central core. Shortly after infiltration, the pain had disappeared. The following day the lesion had regressed, and tenderness was less. The same treatment was repeated. On the fourth day after her first treatment the indurated area was only 3 cm in diameter. The tenderness was gone except about a small peripheral head. A third infiltration was performed, and a fourth was done two days later, at which time there had been little change. A week after the initial treatment the lesion was healed with no evidence of an active infection. There was a residual area of induration with some cyanosis of the overlying skin. A month later there was a small circular scar, 3 mm in diameter. The tissues in the back of her neck were soft and pliable.

Here was a patient who was treated without surgical intervention and hospitalization or removal from her job with excellent results by local infiltration with penicillin.

Cultures were not taken from all of the patients with drainage, but those that were taken showed *Staphylococcus aureus* and/or nonhemolytic *Streptococcus*.

The results of these cases were most gratifying and undoubtedly much more satisfactory than those which follow conventional surgical treatment. Deforming scars were avoided and in many instances the

patients could continue their occupations. Hospitalization, when it was necessary, was greatly shortened. The minimal daily dosage and number of treatments have not been established as yet.

CONCLUSION AND SUMMARY

Regional infiltration of localized infections with penicillin solution is a superior method of therapy. As much as 200,000 units can be infiltrated at any one time into the subcutaneous tissues about an infection without causing toxic reactions or sloughs. Total disability is greatly reduced with this method of therapy and the deformities that result from surgical incision or excision are avoided. Inflammatory pain is quickly relieved after infiltration and this relief is generally permanent after the first or second treatment. Infiltration is moderately painful but the pain does not last more than ten to twenty minutes if the penicillin solution contains 0.5 per cent procaine hydrochloride.

Dr. P. B. Price gave encouragement and helpful criticism.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1945

A Review Prepared by an Editorial Board of the American Academy
of Orthopaedic Surgeons

XIX CONDITIONS INVOLVING THE ELBOW, THE FOREARM, THE WRIST AND THE HAND

Prepared by

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Surgical Anatomy—Kropp⁶⁹² reported a communication between pisotriquetral and radiocarpal joints in 76 per cent of fifty-six joints examined in 28 subjects. Usually this joint is described as completely separated from the cavity of the radiocarpal joint. In only two anatomic atlases was he able to find evidence of the communication between pisotriquetral and radiocarpal joints.

Sunderland⁶⁹³ made a study on the action of extensor digitorum communis, interosseous and lumbrical muscles. The purpose of this paper was to record observations on the actions of these muscles in cases of lesions of peripheral nerves in which conditions were favorable for examination of isolated and combined muscle action. The flexor action of the interossei at the metacarpophalangeal joint and the extensor action of the lumbrical muscles and the extensor digitorum at the interphalangeal joints are contentious points and are given special consideration. The lateral movements of the digits are not included in this study. After a review of the literature, the anatomy is discussed and cases for study are selected in which the third and fourth lumbrical muscles and all interossei participated. Evidently these muscles require assistance of other muscles for their proper functioning. The significant feature of a motor response is the integrated character of the muscular mechanism responsible for it. It is misleading to speak of isolated, individual and specific actions of the extensor, lumbrical and interosseous muscles. They function as a well integrated and coordinated group in every movement of the digits, combining to give that delicacy, refinement and precision of action which forms the basis of manual dexterity. Synergistic control prevents excess expenditure of energy and relieves tension.

692 Kropp, B. N. Note on Piso-Triquetral Joint, Anat. Rec. 92: 91-92 (May) 1945

693 Sunderland, S. Actions of Extensor Digitorum Communis, Interosseous and Lumbrical Muscles, Am. J. Anat. 77: 189-217 (Sept.) 1945

Kaplan¹¹ reported observations on 40 hands dissected personally and 60 observed while being dissected by medical students. He noted there was a constant relation between the tendons of the flexor sublimis and the flexor profundus to the index finger with the median nerve and the palmaris longus tendon. The palmaris longus tendon is used as a key to locate other structures in the wrist. The median nerve and the flexor profundus tendon to the index finger lie directly beneath the palmaris longus tendon, the profundus being more dorsally placed. To the radial side of the median nerve and the tendon of the flexor profundus indicis is found the flexor hallucis longus tendon. To the ulnar side of the deep flexor of the index, but beneath the flexor sublimis to the middle finger, is found the flexor sublimis to the index finger and further ulnarward the flexor profundus to the third, the fourth and the fifth finger in the order named. The tendons of the flexor sublimis to the fourth and the fifth finger lie anterior to the tendons of the respective deep flexor muscles. A discussion of the anatomic variations for the various nerves and tendons is given. The palmaris longus was absent in 11 per cent of the cases according to Le Donble and in 3 of the author's cases and the median nerve may be divided into two trunks. There is frequently extensive fusion of the tendons of the flexor sublimis and the flexor profundus to the fourth and the fifth finger. Various accessory tendon slips may be found as well as variations in the usual tendon pattern.

Another review was on the significance of insertions of the extensor communis digitorum in man, also reported by Kaplan.¹² The tendon of the extensor communis digitorum was dissected in 23 fresh and embalmed human cadavers. It was found that the short insertion into the base of the proximal phalanx occurred in only 38.5 per cent of the 140 fingers examined. Anatomic investigation showed that this insertion contrary to accepted belief is not essential functionally. The action of the extensor apparatus and of the intrinsic muscles of the hand was studied both in the cadaver and by electrical stimulation in more than 100 living subjects. This study emphasized the importance of the connection between the extensor tendon and the capsule of the metacarpopiphalangeal joint in the normal extension of the phalanges. There is a detailed description of the material and methods employed and experimental findings, followed by a discussion.

Osteochondritis Dissecans.—A short general discussion of osteochondritis dissecans is presented by Millman.¹³ A disease of the car-

presented in the literature is given which indicates that the procedure would be surgical excision of the bodies. A report is of a case in which surgical treatment was given.

Kienbock's disease constitutes a convenient clinical designation; this term does not represent a definite pathologic entity according to Etcheverry.⁶⁹⁷ In 1940, the author presented a report on clinical and roentgenologic findings in 2 cases of Kienbock's disease. The patient described in the present paper was 24 years of age and had no history of injury or infection. She had had influenza at 17 years, but had no history of injury. Six months before admission she suffered slight pain in her left wrist. Roentgen examination suggested tuberculosis of the radiocarpal joint, and the latter was immobilized for five months. On removal of the cast, however, symptoms recurred. Examination revealed a swelling of the dorsal surface of the left wrist with slight palmar and cubital inclination. Hyperextension was painful. Roentgen examination revealed changes in the semilunar bone. The role of trauma and syphilis is discussed. Infection constitutes a predisposing factor. Latent inflammation may cause symptoms of aseptic necrosis of bone. Other possible causes include embolic changes, such as treatment of fractures, scaphoiditis and primary occupational disease. A possible embolus during influenza is suggested. This condition is known as an occupational disease of workers employed in coal gas air operations. A detailed description of the specimen is presented. No changes in the vessels could be demonstrated. Anatomic dissection indicates an internal paramedian incision corresponding to the radiocubital articulation below which one will find the semilunar bone in normal subjects.

The various theories as to the causation of Kienbock's disease have been reviewed by Persson.⁶⁹⁸ Conservative treatment and extirpation of the lunate bone have both yielded unsatisfactory results. Hulten explained the predilection for this condition at the wrists as due to the tendency of the radius to protrude over the ulnar end, the so-called minus sign. In 1932 Hulten reported a case in which roentgenologic healing of the lunate occurred two years after shortening of the protruding radius. In 3 other cases in which Persson tried shortening of the radius a satisfactory result was gradually observed in the lunate, but in 2 cases a fracture of the radius occurred in the first plaster of paris bandage. At the place of osteotomy on the radius approximated the ulna and union took place in that position, with resulting limited pronation and supination.

697 Etcheverry, A. J. Los fundamentos anatómicos de la enfermedad de Kienböck, *Amatus* 3:300-310 (May) 1944, Rev. españ. cir., traumatol. 1:331-339 (Nov.) 1944.

698 Persson, M. Pathogenesis and Therapy of Kienböck's Disease. Theory in Light of Efficacy of Operative Shortening of Radius (Hulten) and Lengthening of Ulna, *Acta chir. Scandinav.* (suppl. 98) 92:1-11 (1944).

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articular location, have a uniform pathologic anatomic basis, namely the subchondral epiphyseal necrosis, usually of circumscribed form. The peculiar and constant anatomic position of the necrosis in the different joints with only rare exceptions is evidently determined by the peculiar structure of the joint involved. The static position of a certain portion of the epiphyseal bone in the head of the joint favors development of necrosis as a result of exhaustion fracture. The course and eventual outcome of necrosis of epiphyseal bone depends, furthermore, on the mechanics of the involved joints. In joints with predominant hinge mechanism one usually encounters the dissecans type, and in ball and socket joints the deforming type. A new diagnostic sign for osteochondritis dissecans cubiti is described, i.e., circumscribed sensibility to pressure and percussion of the head of the humerus demonstrable between 14 and 18 years of age. The sign is demonstrable only with the elbow in pronounced flexion. The so-called axial roentgenogram of the elbow joint is indispensable for more accurate demonstration of the focus. The author recommends posterior arthrotomy with a small incision between the olecranon and the lateral epicondyle for exposure of the necrotic focus and for the removal of free joint bodies if the latter are still in the "mouse bed" or in the posterior joint sac.

Instability and Dislocation of Smaller Joints—A discussion of the possibilities of a painful distal radioulnar joint after Colles' fractures is presented by Regan and Bickel.⁷⁰¹ In inadequately reduced Colles' fractures the distal ulnar joint will frequently slip dorsally on rotation. A review of various surgical procedures for correcting this was presented. Two cases were presented in which treatment was by forming a sling with fascia lata to prevent subluxation of the ulna. The fascia lata was threaded through a hole in the distal radius and about the ulna. General discussion of ligamentous and fascial operations to prevent subluxation of various joints was presented.

Eggers⁷⁰² presented a surgical procedure for correction of dislocation of the first carpal metacarpal joint. A surgical procedure is described in which a portion of the extensor carpi radialis longus is split off and threaded through a hole near the base of the metacarpal and sutured back on itself. Plaster fixation was carried out for a period of two weeks, followed by active motion. In a follow-up of ten months there is no evidence of redislocation.

701 Regan, J. M., and Bickel, W. H. Fascial Sling Operation for Instability of Lower Radio-Ulnar Joint, Proc Staff Meet, Mayo Clin 20:202-208 (June 13) 1945.

702 Eggers, G. W. N. Chronic Dislocation of Base of Metacarpal of Thumb, J Bone & Joint Surg 27:500-501 (July) 1945.

A discussion of fracture dislocations of the elbow in children with dislocation of the internal epicondyle into the joint is presented by Schmier⁷⁰⁵. A dislocation of the internal epicondyle into the joint is often unrecognized with resulting serious disability. A method of closed reduction of the dislocated epicondyle is presented. The method includes supination of the forearm and extension of wrist, elbow and fingers, thus putting tension on the muscles attached to the epicondyle, which will in turn reduce it from the joint. The method is not suitable for old cases, in such cases an open reduction is necessary. There may be a stretching of the ulnar nerve at time of dislocation in which a later neurolysis may be indicated. Some cases were presented with a dislocation of the elbow and fracture of the medial epicondyle, which was dislocated into the joint.

Boutrous, Blain and Chipman⁷⁰⁶ report 20 cases of fractures of the elbow treated by nonsplinting and early mobilization. The first 12 cases reported were apparently mild or questionable fractures without displacement which were handled by a sling and early motion. In the second group of cases the fractures were severer and with some displacement of fragments. In this group of cases closed reduction was necessary, with the exception of 2 which required open reduction. In the second group, splinting was used for a short period before the institution of active and passive motion. It was the authors' feeling that a short period of plaster fixation was indicated in many fractures of the elbow. No roentgenograms were shown of the severer fractures, so that the actual situation of fractures cannot be evaluated.

Cox, Parnell and Sobatier⁷⁰⁷ report their experience in acute injuries of the hand in the Mediterranean Theater of Operations. Their early experience was disappointing, and after a plea for discontinuing plaster fixation and traction splints for severe wounds of the hand caused by high explosive missiles, a method of treatment consisting of debridement, preserving all visible tissue, immobilizing with pressure dressing and with the proximal joint in 80 to 90 degree flexion is outlined. It is the thought of the authors that the immobilization of the soft tissue and prevention of swelling and induration as such were more important than the position of the fracture and that the fracture, tendon and nerve repair could be handled after the acute injury had healed.

705 Schmier, A. A. Internal Epicondylar Epiphysis and Elbow Injuries, Surg., Gynec. & Obst. 80: 416-421 (April) 1945.

706 Boutrous, T. A., Blain, A. III, and Chipman, W. A. Nonsplinting Treatment of Elbow Joint Injuries. Report of Its Use in Twenty Cases, Am. J. Surg. 68: 212-218 (May) 1945.

707 Cox, F. J., Parnell, H. S., and Sobatier, J. A. New Type of Hand Dressing to Improve Function, M. Bull. Mediterranean Theat. Op. 2-168-169 (Dec) 1944.

the Zone of the Interior indicated that considerable crippling of hands could have been prevented with proper early treatment in the theater of operation. The most common disability was stiffening of joints from position of the hands and excessive induration and malunion of fractures. The author recommends that splinting should include only the injured portion of the hand. He also advises early action of the muscles and tendons to improve circulation. Granulating areas should be covered with a thin split skin graft. This can later be replaced by a pedicle graft. Malunion can be prevented by early traction in the direction which gives the proper alignment. Many illustrations to show proper method of traction are included.

Nachlas⁷¹² presents a comprehensive discussion of the mechanism of developing a fixed extension contractor of the metacarpophalangeal joint of the hand following injury. He describes the difficulty in restoring function to the metacarpophalangeal joint and presents a type of splint for correction of this deformity. Excellent illustrations of the splint are presented. The splint itself consists of the type frequently used in fractures of the wrist, with addition of the palmar bar which extends anterior to the palm for the purpose of bringing traction straps over to produce constant traction on the metacarpophalangeal joint.

A complete and comprehensive review and recommendations for immobilization of the hand are presented by Pratt⁷¹³. The author emphasizes the importance of observing the best possible functional position of the wrist and digits in immobilization of the hand. Only the minimum amount of rigid fixation compatible with the injury involved is indicated. The metacarpophalangeal or interphalangeal joints should never be immobilized in extension. A satisfactory temporary board and wire splints are shown with wrist cocked up, fingers flexed and thumb free. For effective immobilization, splints or casts must be form fitting and must include at least two thirds of the circumference of the limb. The joints immediately above and below the fracture should be included. If stabilization is required after reduction, skeletal fixation or fixation with a nonpadded or lightly padded cast is recommended. In recent injuries and for more inexperienced surgeons, padding is safer. The cast must be bivalved. The optimum positions for the various joints in fixation are described, including elbow, wrist, palmar arch and thumb. The latter should never be immobilized in the flat or side position, and the fingers never beyond the metacarpophalangeal joints, unless this is definitely indicated and then briefly in semiflexed position. Special care in immobilization for fractures of the metacarpals and phalanges is urged. The metacarpophalangeal joints

712 Nachlas, I W. Splint for Correction of Extension Contractures of Metacarpophalangeal Joints, *J Bone & Joint Surg* 27:507-512 (July) 1945.

713 Pratt, D R. Suggestions on Immobilization of Hand, *Arch Phys Med* 26:649-653 (Oct) 1945.

10 degrees with fingers extended. New plaster was applied in the position of maximum correction and left on for three weeks. Two further changes of plaster were needed before the wrist came into dorsiflexion with fingers extended. It was decided to persevere with splintage. Hyperextension deformity at the metacarpophalangeal joints still persisted and would probably grow worse if the full length plaster was persevered with. Therefore, an anterior plaster slab to hold the wrist in 15 degrees of dorsiflexion was applied with individual splints for each finger (Jones) made from 2 inch (51 cm) cellulose plaster bandages. The patient was encouraged to flex and extend actively at the metacarpophalangeal joints and to report any tendency to flexion. These splints and "cock-up" were renewed twice. After two months the finger splints were discarded, the cock-up splint being retained. Active and passive flexion and extension of fingers were present. The cock-up splint was removed after three months. There was no tendency to relapse.

Thenar Palsy.—A historical discussion of papers dealing with atrophy of the muscles of the thenar eminence is presented by Zachary.⁷¹⁶ An excellent review of the literature is given and reports of cases are summarized. Two cases are reported in which a paralysis of the thenar muscles supplied by the median nerve are presented. It is the author's feeling that the paralysis is due to compression of the median nerve as it passes through the carpal tunnel. In both cases presented there was a history of old injuries to the wrist, and in 1 of them there was a rather sharp bony protuberance over which the nerve passed. In the first case the paralysis was bilateral, and there was little benefit from surgically freeing the nerve. The follow-up was for only three months. There was complete recovery in the other patient as a result of freeing the nerve in the carpal tunnel. Various theories of causation are discussed, and it is his feeling that a portion of a nerve may be involved, thus accounting for motor weakness and normal sensation.

De Quervain's Disease.—Aitken⁷¹⁷ reports a series of 15 cases of de Quervain's disease. It is his belief that the condition is due to the divergence of the tendon of the abductor pollicis longus and the extensor pollicis brevis as it passed the distal end of the bony groove in the distal radial styloid. He considers that the tension exerted repeatedly at a sharp angle produced the thickening of the fibrotic sheath. He also feels that there is a definite relation between this condition and so-called trigger finger or thumb. The condition is more frequently found in women than in men, and it is felt that there will be

716 Zachary, R. B. Thenar Palsy Due to Compression of Median Nerve in the Carpal Tunnel, *Surg., Gynec. & Obst.* 81: 213-217 (Aug.) 1945.

717 Aitken, A. P. Stenosing Tendovaginitis at Radial Styloid Process (de Quervain's Disease), *New England J. Med.* 232: 105-107 (Jan. 25) 1945.

cretinism, achondroplasia, etc., which are diagnostic of the diseases. They feel that a roentgenogram of the hand should be a routine examination and that it would be extremely helpful in differential diagnosis.

A short review of the literature on congenital fusion of carpal and tarsal bone is presented by Henry.⁷²¹ It is the author's conclusion that fusion of the carpal bones is hereditary and that the trait is transmitted according to the mendelian law as a dominant factor which is not sex linked. A report of a case is included.

Wendt, O'Hare and Aronstein⁷²² present an interesting case of sclerodactylyia with atrophy of the terminal phalanges. The patient was a Mexican woman of 43 years who had suffered from tenderness of the fingers for the past six or seven years. No previous roentgen examination had been made, and no diagnosis had been offered. Her fingers and hands were indurated, swollen and red. Pressure at the base of the finger nails caused exquisite pain. Roentgen examination revealed advanced absorption in all the terminal phalanges in both hands except the fifth finger of the left hand. Although a small fragment of bone remained in the distal ends of four of the fingers, the absorptive process had generally progressed so that only a small portion of each phalanx was present distal to the joint. The second and third phalanges of each digit were somewhat narrowed but showed definite evidence of atrophy. The diagnosis was sclerodactylyia associated with destruction of the terminal phalanges.

XX CONDITIONS INVOLVING THE SPINE AND THORAX, EXCLUSIVE OF THOSE IN THE LOWER PART OF THE BACK

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Roentgenography—Rush⁷²³ describes and illustrates a device for spinal fixation and stabilization for roentgenograms of the spine in the standing position. The author feels that this device is helpful, especially when many patients are to be examined and with changing technical personnel.

In pointing out the advantages of this device, he states that fixation and stabilization are assured, that a multiplicity of positions may be obtained by simple maneuvers, that accurate posteroanterior, antero-posterior, lateral and angle positions are assured and can be reproduced at will, and that it provides an accurate means of measuring length of the legs.

721 Henry, M. G. Anomalous Fusion of Scaphoid and Greater Multangular Bone Arch Surg 50: 240-241 (May) 1945

722 Wendt, D. D., O'Hare, I., and Aronstein, E. Sclerodactylyia with Atrophy of Terminal Phalanges, Radiog & Clin. Photog (no 1) 21: 20, 1945

723 Rush, W. A. A Roentgenographic Spinal Fixation and Stabilization Device Am J Roentgenol 54: 187-189 (Aug) 1945

[ED NOTE This device would probably be of value in studying certain spinal lesions when it is desirable to take roentgenograms at intervals with exactly the same position and angle]

Slauson⁷⁻⁴ presents a method for roentgenography of the lateral lumbar part of the spine. He varied the tube-film distance in order to obtain satisfactory roentgenograms demonstrating clearly each intervertebral space, utilizing the divergence of the roentgen beam and distance.

Wilsey, Holly and Cornwell⁷⁻⁵ review the problems of lateral roentgenography in the lumbar lumbosacral region. The authors point out that lateral roentgenography of the lumbar and the lumbosacral region is usually conducted as two separate examinations, since that procedure is most easily adapted to routine exposure technic. There are occasions, however, when for anatomic and economic reasons it is desirable to visualize the lumbar and the lumbosacral region together by means of a single lateral projection on one 14 by 17 inch (35.6 by 43.2 cm) film.

To accomplish this, it requires special precaution in order to secure roentgenograms of good technical quality. The authors discuss the technical difficulties involved and the methods of overcoming them. The discussion covers the use of high kilovoltage technic as a means of visualizing an extensive range of tissue thickness, control of scattered radiation, and roentgen ray filtration for balancing the lumbar and the lumbosacral images. They give illustrations to show the contours of lead mass that have been found practical for alignment with the patient's back to shield the Potter-Buckey diaphragm from direct radiation. Roentgenographic reproductions illustrate improved visualization using lead mass anterior and posterior to the vertebral column compared with those without the lead mass which are fogged by scattered radiation.

Wagoner, Hunt and Pendergrass⁷⁻⁶ continue their work (some of which has been previously reported) on the various roentgen shadows of human vertebral bodies in an excellent article on a study of the relative importance of cortex and spongiosa in the production of the roentgenogram of the normal vertebral body. They discuss the relative "shadow values" of the cortex and of the spongiosa of the vertebral bodies, the transverse markings seen in the lateral roentgenogram of 10 to 20 per cent of human vertebral bodies and the minimum size of a lesion in the spongiosa detectable roentgenographically.

724 Sluson, D. B. A New Principle in Roentgenography of the Lateral Lumbar Spine, *Radiology* **44** 280-282 (March) 1945

725 Wilsey, R. B., Holly, E. W. and Cornwell, W. S. Special Problems in Lateral Radiography of Lumbar Lumbosacral Region, *Radiog. & Clin. Photos* (no 1) **21** 2-8, 1945

726 Wagoner, G. W., Hunt, A. D. and Pendergrass, F. P. A Study of the Relative Importance of the Cortex and Spongiosa in the Production of the Roentgenogram of the Normal Vertebral Body, *Am. J. Roentgenol.* **53** 40-48 (Jan.) 1945

They describe a series of experiments for investigating these points. They conclude that the spongiosa is the more important component in the production of the roentgenographic shadow pattern of the normal vertebral body, that the "transverse line" is due to the presence of a well developed sinusoidal reservoir located within the spongiosa and that the cortex plays no part in the production of this marking. They also conclude that large defects of the lateral cortex are not recorded in roentgenograms and that much smaller defects of the spongiosa are clearly seen.

The author points out that these studies explain why in many instances it is difficult to demonstrate metastatic lesions whether of malignant or infectious origin even in the presence of strong clinical evidence that a lesion may be present, and in practice one not infrequently has to deal with confusing shadows of other structures.

[ED NOTE This paper has numerous, excellent roentgenograms and photographs and is well worth complete study by those interested in roentgenography of the spine.]

Diseases of the Spine—Johnson and James⁷²⁷ report an unusual case of suppurative typhoid of the spine in which a paravertebral abscess formed which perforated into the lung. The length of the latent period, the confusing symptoms and the efficaciousness of treatment were of special interest.

The patient, aged 34 gave a history of typhoid twenty-two years before and complained of intermittent lumbago and sciatica of ten years' duration. Serum agglutinations for typhoid were positive, and aspiration of the abscess showed pure typhoid cultures. Treatment consisted of administration of sulfathiazole, incision and drainage of the abscess, bed rest and use of a back brace. He was followed for two years with progressive improvement and a gain of 70 pounds (31.8 Kg.), and his sedimentation rate returned to normal.

DeGirardier⁷²⁸ reports a case of painful spine with roentgen evidence of rarefaction. The patient was relieved by adequate vitamin C and bed rest. The author feels that this case confirms the work of Mourquind who stressed the importance of vitamin C in calcium metabolism and who also showed cases of decalcification following avitaminosis C. [ED NOTE One wonders whether the patient's relief was due to bed rest or vitamin C.]

Franck⁷²⁹ discusses the surgical treatment of interspinal osteoarthritis ("kissing spine"). He reviews the various causative factors.

727 Johnson E K and James A Suppurative Typhoid Spine Perforating into the Bronchus Case Report Am J Surg 68:103-106 (April) 1945

728 deGirardier J Painful Vertebral Osteonarthrosis with Epiphysial Rarefactions Due to Chronic C Avitaminosis, Lyon chir 37:146-150, 1941-1942

729 Franck, S Surgical Treatment of Interspinal Osteoarthritis ("Kissing Spine"), Acta orthop Scandina 14:127-152, 1943

ussed by Bastrup in 1932, including increased lordosis, an increase in mass in the spinous processes as seen in osteitis deformans, atrophy of vertebral bodies and the intervertebral disk, spondylosis deformans congenital high spinous processes and low vertebral bodies or both anomalies together.

He points out that, while the lesion occurs more frequently in elderly patients, from his experience it may be encountered in the younger age group. He reports the symptoms as occurring in attacks or being of a chronic course with pain on bending forward and backward or straining the lumbar column. In the acute form he suggests only rest and heat. He notes that the chronic forms have been treated with mobilization and with roentgen rays. The operative treatments that have been tried consisted of spinal fusion or partial or total resection of spinous processes involved.

The author reports 54 patients with "kissing spines", of these, 12 were treated operatively with partial resection of the spinous processes selected. Of the 10 operative patients, 4 were relieved, 4 showed improvement and 2 remained unchanged.

The operation was performed only on patients in whom injection of cocaine had relieved the pain.

[ED NOTE Interspinal osteoarthritis (or "kissing spine") is a definite clinical entity, and in selective cases this operative procedure is well worth considering.]

Oppenheimer⁷³⁰ states that anatomic lesions of the spine have a low incidence but produce clinical manifestations in only a minority of cases. He reports a series of 1,824 vertebral lesions of all kinds in which the correlations between clinical and roentgen findings have been analyzed during the past nine years, there were clinical signs and symptoms referable to the vertebral lesion in only 28 per cent of the patients. He discusses the diseases of the vertebral column, separating them into four groups (1) diseases of vertebral bone (spondylosteitis) (2) diseases of vertebral symphyses, (3) diseases of vertebral synovial joints (ankylosis, condylarthritis) and (4) diseases of vertebral ligaments.

He divides the first group (diseases of vertebral bone) into the following groups according to dominant morphologic characters: eroding, predominantly rarefying, predominantly condensing and/or hypertrophic, lesions of growing bone and tumors.

He divides the second group (diseases of vertebral symphyses) into two subgroups: diseases originating in vertebral bone and diseases originating in vertebral disk, and he subdivides the diseases of vertebral synovial joints into acute arthritis, rheumatoid (atrophic) arthritis, ankylosis (hypertrophic arthritis) degenerative articular disease and secondary involvement.

⁷³⁰ Oppenheimer A Diseases of Vertebral Column Roentgenologic Analysis J Roentgenol 53: 348-369 (April) 1945

He concludes that in general the morphologic appearances and clinical manifestations of a given vertebral disease correspond to those of the same disease involving other bones and joints.

Barcelo and Vilaseca-Sabater⁷³¹ present a clinical and roentgenologic study of spondylitis due to brucellosis. They report 40 cases in which the age group was 30 to 50 most commonly. Men were effected six times more frequently than women. In 75 per cent of the cases the condition occurred in the lumbar region, in about 12.5 per cent in the cervical region and in 12.5 per cent in the dorsal area. In 41 per cent there were multiple foci. The vertebral involvement more commonly occurs after two or three attacks of fever, it may occur, however, at any time in the disease. It rarely occurs before the first month but frequently within the first and second months of the disease, though occasionally much later. The vertebral localization was rarely the first symptom and the initial symptoms varied considerably. Pain may increase rapidly. The muscles and involved vertebrae may be tender, lordosis is usually decreased and there is splinting of the spine. The authors point out that it was formerly thought that no abscesses occurred, but in their series about 12.5 per cent had formation of abscess with relatively rapid formation which tended to be subacute and regressed. These abscesses did not usually cause a sinus but occasionally drained spontaneously and absorbed easily after puncture. The pus was usually thick and yellowish green. The culture was rarely positive.

Spastic paraplegia was present in 1 case. The protein in the spinal fluid may be increased, and patients occasionally have meningeal reactions. The roentgen picture is not typical, it may show osteoporosis, osteolysis and osteosclerosis, and it may be similar to tuberculosis or streptococcal involvement.

In the cervical area there is a predilection for the anterior superior angle and the epiphyseal area. In 88 per cent of the 40 cases there were epiphyseal lesions. A narrowed disk with loss of the upper anterior angle is suggestive of this disease. In 65 per cent there were destructive lesions. The posterior elements were rarely attacked and gibbosous formation was rare. In 96 per cent of the cases there were thinned disks. In only 1 case in the 40 was there no apparent disk lesion in a disk. The bodies involved tended to fuse. In the cases of acute disease, osteoporosis without any other bone changes may be noted. In 70 per cent of the cases there were local or diffuse osteophytes. Roentgenologically the authors divided the group into osteolytic, without formation of bone and similar to Pott's disease (tuberculosis of vertebrae), 23 per cent mixed forms of relatively equal destruction and proliferation, 38 per cent and (3) hard or osteophytic reaction with little osteolysis.

⁷³¹ Barcelo P and Vilaseca-Sabater, J M Undulant Fever Spondylitis Clinical and Roentgen Study, Med clin Barcelona 3 184-198 (Sept) 1944

This group was hard to distinguish from osteoarthritis. The progress is more rapid than in Pott's disease and usually more acute. The localization is usually in the spongy bone, and proliferative changes are early in this condition while late in Pott's disease. The differential diagnosis especially from osteomyelitis is difficult. It may be almost identical with osteomyelitis due to typhoid and differentiated only by serologic tests. The prognosis is good if treatment is early. The pain disappears rapidly and the abscess absorbs. Sometimes recovery is so complete that it is difficult to find residual effects by roentgen examination.

For treatment bed rest may be sufficient if pain is not severe, but the authors recommend early immobilization to relieve pain and point out that the pain is usually not relieved by analgesic drugs.

Roentgen treatment gave inconstant results. They recommend anti-brucellosis serum, and they use vaccine if the fever is slight. They now use a specific intravenous vaccination and when in doubt use this as a therapeutic test. They feel that a strong febrile reaction after the intravenous administration of vaccine is a specific test for brucellosis. The first dose is given slowly in the morning with the patient fasting. Usually a chill occurs five to six hours later and lasts about thirty minutes, followed by a sensation of heat for three hours and elevation of temperature to about 104 F.

[ED NOTE This is an interesting paper on spondylitis due to brucellosis. Some of the roentgenographic reproductions (especially those with abscess formation) might easily be considered tuberculosis.]

Anomalies and Fractures of the Ribs—Hagen⁷³² reports an interesting case of multiple fractures of the ribs in which treatment was with a Drinker respirator. He briefly reviews the physiologic aspects of the problem of the so-called "stove-in" chest and summarizes the various methods which have been used and suggested for the treatment of the patient with a severely crushed chest. He reports a 46 year old man with fractures of the second to the eleventh rib on the right side and fractures of the second to the twelfth rib on the left with overriding of the fragments of the second, the fourth and the fifth rib.

The respirator was adjusted to provide a negative pressure of 20 mm of mercury intermittently at a rate of 36 cycles per minute. The valves were carefully adjusted to avoid positive pressure, inasmuch as it was felt that the patient needed only expansion of the chest by artificial means. Within an hour after being placed in the respirator the patient showed improvement. By the next day he was able to do without an oxygen tent and to have the rate of the respirator reduced to 28 per minute. Three days later he was comfortable with the rate of the respirator at 21 per minute. The patient was removed from the respirator

732 Hagen K. Multiple Rib Fractures Treated with Drinker Respirator Case Report J Bone & Joint Surg 27:330-334 (April) 1945

ten days after the injury and made an excellent recovery with good healing in all the fractures.

The author points out that the patient did not experience shock, unlike most persons similarly injured, but did experience hypertension, which may have been due to the profound retardation of circulation produced by the loss of normal fluctuating negative intrathoracic pressure. The hypertension was quickly relieved when the cardiorespiratory function was restored to normal by the respirator.

The author concludes that wherever a Drinker respirator is available it is a much simpler treatment to apply than other procedures used to accomplish stabilization of the thoracic wall. It avoids the obvious risk of surgical treatment and the danger of infection associated with traction hooks in the sternum or the ribs. It also exerts a gentle non-mechanical expanding effect on the "stove-in" chest.

[LD NOTE While this is a report of only a single case, the dramatic improvement produced by the use of a Drinker respirator suggests that it be tried more frequently in these problems.]

Bond⁷³³ discusses spontaneous fractures of the ribs in healthy persons and reports 3 cases. He feels that while many cases of fractured ribs from coughing in patients with tuberculosis are reported, these fractures are attributed to the decalcification of the bones and the general debility of the patient rather than to contracture of muscles. In his opinion, it is a fatigue fracture similar to the march fracture. He feels that the mechanism is similar and the movements of the ribs are comparable to the movements of and stress on the metatarsal bone.

Proctor, Campbell and Abramson⁷³⁴ state that no mention can be found in the literature of fatigue fracture of the first rib. They quote Ingersoll's statement that fatigue fracture is a desirable term that denotes those fractures occurring in normal bone from repeated micro-traumas and subfractural mechanical injury. The process is a gradual one involving continual rhythmic stress on the soft tissues supporting the bony structure. When the muscles, ligaments and tendons lose their tone the supporting function of these tissues is lost, allowing most of the stress to fall on the bone. When the bony structure itself is fatigued, fracture occurs where the stress is greater. They believe that fracture of the first rib can occur under circumstances which conform with these principles. The authors report 3 cases in which fractures of the first rib were sustained after the carrying of heavy barrack bags.

733 Bond T B Spontaneous Fractures of the Ribs in Healthy Individuals Texas State J Med 40 642-643 (April) 1945

734 Proctor S E, Campbell, T A, and Abramson, A. S March Fracture of First Rib (Barracks Bags Fracture), Bull U S Army M Dept, June 1945, no 89 pp 101-105

Bowie and Jacobson⁷³⁵ discuss anomalous development of the first rib simulating isolated fracture. They present reproductions of roentgenograms of 9 out of a series of 17 personally observed cases of changes in the first rib simulating fracture, and they amplify the hypothesis that these changes, callus-like formation and pseudarthrosis, are due to anomalous development. They emphasize the frequency of the occurrence of these changes and the probability that these apparent congenital changes may be mistakenly diagnosed as isolated fractures of the first rib, particularly of the spontaneous variety.

Gershon-Cohen and Delbridge⁷³⁶ also write on pseudarthrosis, synchondrosis and other anomalies of the first rib. They briefly review the usual anomalies of the first rib and demonstrate congenital synchondrosis because of its similarity to pseudarthrosis following ununited fracture. They feel that pull of the muscles seems to be a just cause of fractures of the first rib as in the lower ribs and that such fractures may occur without immediate recognition. Later, however, they may be observed incidentally in roentgenograms of the lungs. Pseudarthroses may be found rarely in both first ribs. They report 1 such case and review 3 other previously reported cases. They conclude that most anomalies of the first rib are not clinically significant but the differential diagnosis between congenital synchondrosis, fracture pseudarthrosis and pathologic fracture may be important, and yet not easily made if there is an unsatisfactory history of injury or if metastatic malignant disease is suspected.

[ED NOTE These three papers on anomalies and fractures of the first rib suggest that the differential diagnosis may be difficult even with adequate roentgenograms, and it is probably impossible in the review of the literature accurately to differentiate between fracture and anomaly in any of the reports of cases.]

Scoliosis—Schwartzmann and Miles⁷³⁷ report their experimental results in the production of scoliosis in rats and mice. They review briefly the previous attempts of various workers to produce scoliosis experimentally in animals. In the experiments undertaken in this study the objective was (1) to determine the effect on the alignment of the vertebral column of muscular imbalance produced by unilateral excision of groups of symmetric muscles which influence the movements and position of the vertebral column and (2) to determine the effect on the alignment of the vertebral column of muscular imbalance brought about

735 Bowie, E. R. and Jacobson, H. G. Anomalous Development of First Rib Simulating Isolated Fracture. Am J Roentgenol 53: 161-165 (Feb.) 1945.

736 Gershon-Cohen, J. and Delbridge, R. E. Pseudarthrosis, Synchondrosis and Other Anomalies of the First Ribs. Am J Roentgenol 53: 49-54 (Jan.) 1945.

737 Schwartzmann, I. R. and Miles, M. Experimental Production of Scoliosis in Rats and Mice. J Bone & Joint Surg 27: 59-69 (Jan.) 1945.

by the operative release of the muscles from their attachments to the vertebrae and the prevention of their reattachments by the interposition of inert material between the muscle mass and the vertebra to which it was attached.

The authors studied the effects of unilateral removal of superficial and deep back muscles in rats. They also studied bilateral removal of superficial and deep back muscles in rats and removal of superficial and deep muscles on one side, and release of muscle attachment to spinous processes, laminas and transverse processes on the opposite side, with the interposition of an inert material to prevent reattachment.

They also studied bilateral but asymmetric excision of superficial and deep muscles. Their experiments include a series of 43 laboratory animals, and they have demonstrated that scoliosis can be produced in quadrupedal animals when muscular imbalance is obtained in those groups of muscles affecting the alignment of the vertebral column. It is also apparent that a definite time element is necessary for the scoliosis to be produced.

The authors conclude 1 Scoliosis can be produced experimentally in laboratory rats and mice by the selective release of mechanical action of different groups of muscles on the vertebral column. 2 A satisfactory degree of control can be maintained to allow the prediction of the type of curve to be produced. 3 Selective muscular imbalance can be produced without excision of muscles by the use of inert material to prevent reattachment of muscles. This imbalance will produce lateral curvature. 4 Excision and release of muscles which did not produce imbalance resulted in no scoliosis in the animals studied.

In the animals studied the use of "insultic" membrane was found to be the most satisfactory, since microscopic sections through the areas of implantation of inert material showed that no local reaction of the tissue to the introduction of this substance was encountered, whereas considerable fibrosis and scarring were present around the insertions of cellophane and rubber dam [ED NOTE The effect of this fibrosis in the production of the ultimate curves must also be considered]. They state that in this experiment there have been demonstrated, *in vivo*, some of the mechanical imbalances presented by Carey in an inanimate model. Thus scoliosis has been produced by selective muscular imbalance, which simulates the mechanical condition of paralytic scoliosis [ED NOTE It should be remembered that, as the authors point out, they produced scoliosis in quadrupedal animals and that this experiment does not include the additional problem of human paralytic scoliosis, in which the effect of the suprincumbent weight and the upright position is an added factor]. In an effort to produce results earlier, the mice in experiment 2 were worked on a treadmill since it was felt that in a system of

muscular imbalance regular exercises would increase the power of stronger or unopposed muscles and thereby would cause the scoliosis to appear sooner. They feel that this contention is supported by the results, since curvature appeared as early as one month after operation in these mice. Definite evaluation of the influence of exercise on the time required for the production of curvature in such an experiment, however, calls for a series comparable except for exercise in the same type of animal.

[ED NOTE This is an interesting and valuable experimental work, but one must remember that there is considerable difference between these experimental results and what one may find clinically in paralytic scoliosis in the human being. In these experiments the effect was the total removal of the forces of certain selected muscles, whereas in poliomyelitis involving the trunk or spinal muscles there may be considerable variation in the degree of involvement of muscles, and it is difficult to determine how much involvement there is in one group or which muscles are actually involved. Furthermore, these results are based on the excision of large areas of the musculature of the back, whereas in the human being there may be many thousands of possible permutations and combinations of muscular imbalance. It is difficult or impossible to predict what the forces are when there are so many possible permutations and combinations in human scoliosis due to poliomyelitis.]

Osteochondritis of the Ribs—Lindblom⁷³⁸ briefly reports on the use of roentgenography as an aid in the diagnosis of osteochondritis in the anterior ends of the ribs. He reports 12 patients operated on for established osteochondritis in 11 of whom roentgenographic changes were observed. He also reports 26 patients suspected of having osteochondritis but without operation, in 8 of whom roentgenographic changes were present and in 18 absent. The study also includes 16 normal anatomic specimens and a study of 4 patients operated on without roentgenographic examination and 4 patients with costo-ostitis operated on during the same period.

He states that in all of the cases of osteochondritis the roentgenograms showed a local swelling of the soft tissues on the inner side of the cartilage or at the junction between the cartilage and the bone. The suspected area was studied on tangential films. The swelling varied in thickness in different cases from 2 mm to 2.5 cm. In most instances the swelling was situated at the level of the second rib. In the other cases it was noted in the region between the third and the sixth rib. Besides the swelling, signs of calcium deposit were present in 2 cases. It was difficult to distinguish these from the normal calcifications of cartilage.

738 Lindblom K. Subcostal Swelling of Soft Tissues in Osteochondritis, Acta radiol 25: 610-613, 1944.

At operation an abscess of granulation tissue was found around the cartilage or at the junction of the rib and the cartilage

He concludes that local swelling of the subcostal soft tissues at the cartilage or the cartilage and bone line is strong evidence of osteochondritis, while if these parts have a normal appearance the presence of this disease is unlikely, provided that there are no fistulas through which an abscess might have drained. The author describes the results of the study of the anterior ends of the ribs seen on tangential films and demonstrates that osteochondritis is usually accompanied by a noticeable swelling of the subcostal soft tissues [ED NOTE Some of these cases were of tuberculous osteochondritis]

Intervertebral Disk—Knutsson⁷³⁹ reports 140 cases and discusses the instability associated with degeneration of the disk in the lumbar part of the spine. He points out that anatomic specimens of the lumbar part of the spine have shown that degeneration of the disk (osteochondrosis) causes abnormal movement between the vertebrae, and it has been assumed that the clinical symptoms of this degeneration are due to this instability. In addition to the usual roentgenograms of the lumbosacral area taken with the patient lying down, the author includes profile roentgenograms taken with the patient standing and bending as far forward and backward as possible in order to make a functional test of the stability of the disk junction. By this means he was often able to demonstrate abnormal movements between the vertebrae due to loss of stability. In 71 cases the results were negative, signifying that the vertebrae and the intervertebral spaces were free of changes and that there was no instability. Of the 69 cases with degeneration of disks, in 52 only one disk was involved, in 16 two disks were affected, and in 1 three disks were affected.

Weens⁷⁴⁰ discusses calcification of the intervertebral disk in childhood. The author reports 1 case of calcification of the disk in childhood and reviews 5 cases from the literature. All these cases were characterized by an acute episode of pain in the region of the involved segment of the spine, limited motion and spinal deformity. Rapid change in the size of the calcification or complete absorption was noted in 5 of the 6 cases described. Calcification of the nucleus pulposus in adult life is as a rule a stationary process of little clinical significance, but rather striking clinical symptoms were encountered in the cases described in childhood. In all cases reported complete recovery occurred.

The author feels that recognition of this syndrome is important in the differential diagnosis of meningitis, myositis and diseases involving the vertebrae and the spinal cord.

739 Knutsson F. The Instability Associated with Disc Degeneration in the Lumbar Spine. *Acta radiol* 25:593-609, 1944.

740 Weens H S. Calcification of the Intervertebral Discs in Childhood. *J Pediat* 26:178-188 (Feb) 1945.

Friedman and Read⁷⁴¹ briefly review the subject of orthostatic albuminuria, pointing out that mobilization of masses of young persons has stressed the importance of this condition. They point out that the cause of this condition is still unknown, but it is generally believed that orthostatic albuminuria is due to some disturbance of the renal circulation leading to congestion and venous stasis induced by the upright position. They describe provocative tests of lordosis and the use of these tests in the lordotic type of orthostatic albuminuria. They report a series of 5 orthopedic patients wearing hyperextension body casts for from two to four months or more for all of whom repeated studies of the urine disclosed no albumin and renal function remained unimpaired. Six patients with unrelated medical and surgical conditions were placed in exaggerated lordosis for periods of one to two hours. All these patients had normal urine, and the appearance of albumin could not be induced. The authors believe that these observations confirm the fact that although lordosis plays a role in the pathogenesis of orthostatic albuminuria in susceptible persons it has no influence in producing albumin in normal nonsusceptible persons.

XXI CONDITIONS INVOLVING THE LOWER PART OF THE BACK

Prepared by

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THE YEAR 1945 produced a considerable number of useful articles on the subject of pain in the lower part of the back and sciatic pain. Intervertebral disk syndromes occupy the predominant place in this literature. The importance of rupture of the intervertebral disk in causing sciatica is firmly established, indeed chief controversy now centers about the question whether almost all sciatica may not be the result of protrusion of the disk. Increased attention is being devoted both to early traumatic lesions of the disk and to degenerative changes secondary to aging and to chronic minor trauma. Concerning detailed diagnostic and therapeutic indications there is as yet little unanimity.

In this review the policy of abstracting the more outstanding articles and of calling attention to the remainder of the year's literature has again been followed.

Pain in the Lower Part of the Back — An interesting development is the tendency in many quarters to regard early or minor traumatic lesions of the lumbar intervertebral disks as a frequent cause of pain in the lower part of the back in the absence of sciatica.

⁷⁴¹ Friedman A I and Read H S Orthostatic (Lordotic) Albuminuria Including Studies on Patients in Hyperextension Body Casts New York State Med 45 2075 2078 (Oct 1) 1945

Kev⁷⁴² believes that the cause of idiopathic pain in the lower part of the back is practically always intraspinal and in over 90 per cent of the cases a lesion of the intervertebral disk. He states that in most cases the symptoms subside spontaneously or yield to conservative treatment and that in only about 10 per cent is an operation the treatment of choice. Cyriax⁷⁴³ believes that pressure on the dura mater exerted by a defective annulus fibrosus via the posterior longitudinal ligament is the cause of lumbago, he recommends epidural anesthesia if the symptoms do not subside after a few days of rest in bed. Shapiro⁷⁴⁴ also has written on the use of transsacral injection of procaine for pain in the lower part of the back. In the Scandinavian literature, Waldenstrom⁷⁴⁵ has discussed the relationship of lumbago and herniation of the intervertebral disk, and Knutsson⁷⁴⁶ has described instability associated with degeneration of the disk in the lumbar part of the spine.

Crisp⁷⁴⁷ agrees that pain in the lower part of the back results from damage of the intervertebral disk, believes that early diagnosis can be made and makes a plea for thorough early treatment designed to forestall herniation and sciatica. He states that the cases of pain in the lower part of the back in which if the patient is untreated sciatica will eventually develop are characterized by extreme and persistent spasm of the lumbar portion of the erector spinae muscle with a resultant lumbar lordosis. The patient complains of a continuous aching lumbar pain which is aggravated by movement and coughing and may radiate into the groin. He shows tenderness to deep pressure over the sacroiliac joint and the interspinous ligament of the affected segment, scoliosis is unusual at this stage but as the lesion progresses may be produced by hamstring spasm on the affected side. For these patients the author advises hospitalization and complete rest either in bed or in a plaster jacket. He believes that in early cases the lesion may be a minor tear of the annulus fibrosus without protrusion of the disk and that the spastic

742 Kev, J A. Intervertebral Disk Lesions Are Most Common Cause of Low Back Pain With or Without Sciatica, Ann Surg **121** 534-544 (April) 1945 Intervertebral Disk Lesions Are Most Common Cause of Low Back Pain With or Without Sciatica, Tr South S A **56** 150-160, 1944

743 Cyriax, J A. Lumbago Mechanism of Dural Pain, Lancet **2** 427-429 (Oct 6) 1945

744 Shapiro, L. Low Back Pain Treatment by Nerve Block, Indust Med **14** 580 (July) 1945

745 Waldenstrom, H. Lumbago and Intervertebral Disk Herniation, Acta chir Scandina **91** 11-16, 1944

746 Knutsson F. Instability Associated with Disk Degeneration in Lumbar Spine, Acta radiol **25** 593-609, 1944

747 Crisp, E J. Damaged Intervertebral Disk Early Diagnosis and Treatment Lancet **2** 422-442 (Oct 6) 1945

lordosis is a natural protective mechanism relieving strain and effecting splintage at the level of injury. If the back is protected in a position of lordosis, healing and fibrosis may take the place under the influence of circulation from the posterior longitudinal ligament, together with adaptive shortening of the muscles and ligaments and the production of a permanent protective lordosis. On the other hand, if the diagnosis is not made early and the back remains unprotected, the tear of the annulus gradually increases and leads finally to complete rupture of the fibrocartilage, herniation of the nucleus and the development of sciatica. Crisp thinks that with treatment with a body cast the prognosis for cure is good. Patients with sciatica may be treated by application of a cast with the lumbar part of the spine in kyphosis. After a month or so the herniation is found to be reduced and a cast in the position of lordosis may be used.

A timely warning, however, that the injured intervertebral disk is but one of many causes of backache and sciatica is sounded by Compere.⁷⁴⁸ Tippett⁷⁴⁹ reviews the symptoms and signs of conditions which cause backache. Samson,⁷⁵⁰ editing a symposium from the Hospital of the Sacred Heart in Montreal, stresses the many and varied causes of pain in the lower part of the back. This group of articles,⁷⁵¹ published in the French language, describes the anatomy and physiology of the lower part of the back, the signs and symptoms of cases of pain in the lower part of the back and sciatic pain and the traumatic, mechanical, degenerative, developmental, infectious and arthritic types of syndromes involving the lower part of the back. Included also are discussions of generalized diseases of bone with lumbar manifestations, arthritis of the lumbosacral articular facets and industrial disabilities of the lower part of the back.

748 Compere, L A Backache with Sciatic Pain, Proc Intern Postgrad M A North America (1944), 1945, pp 184-188

749 Tippett, G O Diseases of the Spine and Sacro-Iliac Joints Post-Grad M 1 21 68-72 (Feb) 1945

750 Simson, J E Diagnostic differential Symposium sur le syndrome douloureux lombo-sciac Union med du Canada 74 1136-1138 (Aug) 1945

751 Fortier, M Lesions infectieuses vertebrales lombo-sacrées Union med du Canada 74 1099-1106 (Aug) 1945, Affections de la sacro-iliaque ibid 74 1107-1112 (Aug) 1945 Frenette, U Les anomalies congenitales lombo-sacrées, ibid 74 1091-1099 (Aug) 1945 Grisepi, R Sémioptologie des syndromes douloureux lombo-sacrées ibid 74 1069-1076 (Aug) 1945 Lepine, E Anatomie de la région lombo-sciac Symposium sur le syndrome douloureux lombo-sciac, ibid 74 1051-1057 (Aug) 1945 Lehoume L Syndrome lombo-sciac par lésions vertebrales multiples osseuses généralisées à manifestations vertebrales et ostéoporose d'origine endocrinienne ibid 74 1112-1116 (Aug) 1945 Potvin P Les déformations mécaniques et statiques lombo-sacrées ibid 74 1082-1088 (Aug) 1945 Lesions des tissus mous dans la lombalgie ibid 74 1088-1091 (Aug) 1945 Simson J E Arthrite chronique atopique (symposium sur le syndrome douloureux lombo-sacrées), ibid 74 1117-1126 (Aug) 1945

Hauser⁷⁵² believes that inflammation of the lower part of the back resulting from mechanical strain is a much more frequent cause of backache than a slipped intervertebral disk. He stresses the point that pain in the lower part of the back may be produced by physiologic changes in the absence of outstanding structural abnormalities. He applies the term "functional decompensation" to the imbalance between the loads which the back is called on to bear and its capacity to withstand these loads. Factors tending to produce such decompensation are obesity, excessive physical activity, debilitating diseases and poor muscle tone. The influence of inadequate exercise, poor hygienic conditions and improper diet is discussed. The symptoms referable to the back are primarily those of fatigue, pain in the lower extremities is presumably of referred type attributable to inflammation of muscle or joint and the resulting reflex muscle spasm. Irritation over a long period of time may lead to sensory disturbances and impairment of muscle tone. Increase of the normal curvatures of the spine results in poor posture. The physical signs of functional decompensation of the back are faulty posture, decreased muscle tone and a positive straight leg raising sign. Additional changes observed in the acute stage include spasm of the lumbar muscles, decreased lumbar lordosis, tilting of the pelvis and scoliosis.

In a second article Hauser⁷⁵³ reviews the clinical picture of functional decompensation and recommends the use of a corrective body cast. This is applied with the patient standing in a flexed position in order that when he afterward stands erect the excessive lumbar lordosis and dorsal kyphosis may be corrected.

Methods of care at home and personal conduct designed to relieve the patient with a strained back have been described by Heller⁷⁵⁴.

Fox⁷⁵⁵ reports in the neuropsychiatric literature his observations on a series of soldiers with backache, all of whom were first examined by an orthopedist and then referred routinely for psychiatric consultation. Most of the patients exhibited poor posture. They were treated by physical therapy with emphasis on the correction of postural defects. The treatment was thought to be of great value in improving morale as well as posture and backache. The author advisedly points out the

752 Hauser E D W Low Back Pain Due to Functional Decompensation of Back Wisconsin M J 44 869-873 (Sept) 1945

753 Hauser E D W Corrective Cast for Treatment of Low Back Pain, I A M A 128 92-93 (May 12) 1945

754 Heller E P Back Saving Outline of Home Care and Personal Conduct Indust Med 14 508 (June) 1945

755 Fox H M Treatment of Soldiers Complaining of Backache Some Observations Concerning Posture and Attitude J Nerv & Ment Dis 102 154-164 (Aug) 1945

need of cooperation between orthopedist, psychiatrist and physical therapist in the treatment of soldiers with backache

Pain in the lower part of the back ascribed to the herniation of fascial fat is discussed by Herz⁷⁵⁶. He reports 6 operative cases, in only 1 of which the fatty mass had a discernible pedicle. In all cases relief of pain followed excision of the fatty tissue. Microscopically these small masses consisted principally of fat with areas of fibrous tissue, congested blood vessels, edema and focal hemorrhage. In 1 specimen nerve tissue was found. The histologic diagnosis was fibrolipoma. Mylechreest⁷⁵⁷ reports his observations on dissections of the back for the study of fat patterns and on 4 patients whose symptoms were completely relieved after the removal of small fatty masses.

An article on estimating disabilities of the back has been contributed by Lewin,⁷⁵⁸ and Stark⁷⁵⁹ has discussed pain in the lower part of the back in the Army Specialized Training Program.

Osteitis condensans ilii is the subject of an article by Hare and Haggart⁷⁶⁰, they report 23 patients, all of whom were women of child-bearing age. This condition, first described in 1926, is characterized clinically by recurrent attacks of pain in the lower part of the back and in the pelvis and roentgenographically by a condensation of iliac bone adjacent to the sacroiliac joint without involvement of the joint space or of the sacrum. For most cases the conservative measures of rest, physical therapy and a support for the lower part of the back constitute adequate treatment. Hare and Haggart describe the differential characteristics which they use in distinguishing osteitis condensans ilii from arthritis of Marie-Strumpell type.

Sciatica—Increasing emphasis on the ruptured lumbar disk as the cause of most instances of sciatic pain makes it important to remember that other lesions may produce this symptom. The year's articles on sciatica include references to such lesions as well as to therapeutic methods designed primarily for the symptomatic relief of sciatic pain.

Magnuson⁷⁶¹ points out that narrowing of the intervertebral disk space is a frequent occurrence and that little narrowing is required to

756 Herz, R. Herniation of Fascial Fat as Cause of Low Back Pain with Relief by Surgery in Six Cases J. A. M. A. **128** 921-925 (July 28) 1945

757 Mylechreest, W. H. An Investigation into the Aetiology and Pathology of Fibrositis of the Back Ann. Rheum. Dis. **4** 77-79 (June) 1945

758 Lewin, P. Estimation of Back Disability Reduced to Simple Mathematical Formula Indust. Med. **14** 571 (July) 1945

759 Stark, L. I. Low Back Pain in Army Specialized Training Program Journal-Lancet **65** 223-225 (June) 1945

760 Hare, H. F. and Haggart, G. E. Osteitis Condensans Ilii J. A. M. A. **128** 723-727 (July 7) 1945

761 Magnuson, P. R. Intervertebral Disk Am. J. Surg. **67** 228-231 (Feb.) 1945

cause compression of a nerve root in its intervertebral foramen. From roentgenographic studies of the spine in flexion and in hyperextension, Capener⁷⁶² concludes that the meninges and the cauda equina may be under tension when the back is flexed. He also believes that when the spine is sharply flexed the quadratus lumborum may at times go into spasm to act as an abnormal flexor. Sciatica has been discussed also by Campbell,⁷⁶³ and its association with pain and deformity of the back has been emphasized by Wardle.⁷⁶⁴

Holmes and Sworn⁷⁶⁵ report 3 instances of macroscopic pathologic changes in nerve roots in the absence of protrusion of an intervertebral disk. The clinical picture of these cases was indistinguishable from that of a ruptured intervertebral disk. In 2 instances the root was edematous, and in the third adhesions were present around the root in the spinal canal. Diagnoses of sciatic neuritis were made, the causation was not determined with certainty.

Clavel and Meneault⁷⁶⁶ report laminectomy and resection of strangulating adhesions of the dural cul-de-sac. Briggs and Krause⁷⁶⁷ discuss the indications, technic and results of intervertebral foraminotomy for the relief of sciatic pain, basing their study on a series of 35 cases. This operative procedure converts the closed canal of the intervertebral foramen into an open trough by removal of the articular processes and facets. The authors feel that the indications for foraminotomy are (1) failure of simple laminectomy with complete exploration of the accessible nerve root within the neural canal to reveal the impinging mass, (2) complete or considerable collapse of the intervertebral disk space with or without hypertrophic lipping as seen in the roentgenogram, and (3) persistent sciatic pain following a spinal operation with or without fusion. Sufficient bone, ligamentum flavum and capsule are removed to allow visualization of the nerve root along its entire course until it passes into soft tissue. The operation is completed by placing a small piece of muscle tissue over the exposed nerve root and by carrying out spinal fusion. At the 35 operations, the following lesions were found:

762 Capener N. *Sciatica. Anatomical and Mechanical Study of Lumbo-Sacral Region*, Ann Rheum Dis 4:29-36 (Dec) 1944

763 Campbell J F M. *The Sciatic Syndrome*, J Roy Nav Med Serv 31:24-25 (Jan) 1945

764 Wardle, E N. *Sciatic Pain Its Relation to Pain in the Back and Spinal Deformity*, M Press 213:197-201 (March 28) 1945

765 Holmes J M and Sworn, B R. *Sciatic "Neuritis,"* Brit M J 2:350-351 (Sept. 15) 1945

766 Clavel C, and Meneault. *Nevralgie sciatique gauche Laminectomie Re-section d'un bide étranglant le cul-de-sac dural*, Lyon chir 37:114-115, 1941-1942

767 Briggs H and Krause J. *Intervertebral Formaminotomy for Relief of Sciatic Pain*, J Bone & Joint Surg 27:475-478 (July) 1945

(1) diminution of foraminal space secondary to thinning of the intervertebral disk, (2) hypertrophic lipping of the posterior periphery of the vertebral bodies (this hypertrophy was often cartilaginous and absent in the roentgenogram), (3) herniation of the disk into the intervertebral foraminal space, and (4) impaction of nuclear material within the foramen after migration from a distant point of rupture. The relief of sciatic pain within a follow-up period of from three months to four years was complete in all cases except 3 which the authors consider unsolved diagnostic problems [Ed Note This percentage of relief is high, especially in view of the fact that 25 per cent of these patients had been subjected previously to spinal fusion with or without removal of a herniated disk and that all had had long intervals of rest, use of a brace and other conservative measures before foraminotomy. As stated by the authors, the follow-up period is too short to allow of conclusive evaluation.]

In foreign literature, Sahlgren and Sjögren⁷⁶⁸ have discussed myalgic pressure points in sciatica, and Brüel⁷⁶⁹ and Vaubel⁷⁷⁰ have described the treatment of sciatic pain by injections of procaine hydrochloride. Articles on epidural injection have been published by Galbriati⁷⁷¹ and Decourt⁷⁷².

Intervertebral Disks.—Articles on the intervertebral disk include studies of its pathologic lesions, reviews of the ruptured disk syndrome, contributions to the diagnosis of herniation of the disk and reports on therapeutic indications and results.

In three articles published in the *Journal of Bone and Joint Surgery*, Coventry, Ghormley and Kernohan⁷⁷³ record the results of their study of the microscopic anatomy and pathology of the intervertebral disk. Specimens from 88 necropsies were examined roentgenographically and microscopically. The first article of this series deals with the anatomy, embryology and physiology of the disk. The second presents a descrip-

768 Sahlgren, E., and Sjögren, O. So-Called Myalgic Pressure Points in Sciatica, *Nord. med. (Helsing)* **22** 1141-1142 (June 16) 1944.

769 Brüel, O. Relief of Pain as Therapeutic Measure Impletol in Common Painsful Conditions, *Nord. med.* **21** 190-196 (Feb 4) 1944.

770 Vaubel, E. Die Injektionsbehandlung der Schmerzzustände im Gebiet des Nervus ischiadicus, *Deutsche med. Wochenschr.* **70** 28 (Jan 21) 1944.

771 Galbriati, R. Contribución al tratamiento de la ciática fumicular o neurodócesis por la vitamina B₁ epidural. *Semanas med.* **2** 630-632 (Sept 10) 1942.

772 Decourt, J. Is It Necessary to Renounce Epidural Injections of Iodized Oil (Lipiodol) in the Treatment of Sciatica? *Rev. neurol.* **75** 192-194 (July-Aug) 1943.

773 Coventry, M. B., Ghormley, R. K., and Kernohan, J. W. Intervertebral Disc. Its Microscopic Anatomy and Pathology. I. Anatomy, Development and Physiology, *J. Bone & Joint Surg.* **27** 105-112 (Jan) 1945. II. Changes in the Intervertebral Disc Concomitant with Age, *ibid.* **27** 233-247 (April) 1945. III. Pathological Changes in the Intervertebral Disc, *ibid.* **27** 460-474 (July) 1945.

tion of changes in the normal disk in successive decades of life. The third article concerns pathologic changes, these include hypertrophic arthritis, nuclear expansions, ballooned disks, thinned disks, nuclear protrusions calcification of the nucleus pulposus, infections of the disk and invasion by malignant tumors. The authors point out the difficulty of distinguishing in many cases between degenerative changes which normally accompany the aging process and those which should be termed pathologic. [ED NOTE These observations are fundamental to an understanding of intervertebral disk syndromes, they should be studied in detail in the original paper.]

Mooney⁷⁷⁴ reviews the pathologic changes which take place in the intervertebral disks with increasing age and the clinical pictures which these changes may produce. He discusses and illustrates the escape of nuclear material into the substance of a vertebral body, he believes that such lesions cause backache which subsides as a bony barrier is formed about the extruded nuclear material. The author contrasts this lesion of limited protrusion of central nuclear material with that occurring in tuberculosis when the nucleus bursts unopposed through a destroyed cartilaginous plate, leading to complete collapse and destruction of the disk. Mooney believes that Scheuermann's disease is definitely an osteochondritis of the ossific nuclei of the vertebral epiphyseal groove rather than a lesion of the intervertebral disk. Three types of posterior lesion of the disk are described (1) a simple annular tear with a central nucleus undisturbed and taking no part in the extrusion, (2) an annular tear with a posteriorly situated nucleus which ruptures and adds greatly to the bulk of the extruded tissue, and (3) an annular tear with an intact or practically intact posterior nucleus which protrudes as a glistening mass, lifting up the dural sheath. Mooney also describes the degeneration and thinning of the disk which begin at about the age of 40 years and the posterior nodal protrusions which are localized degenerative changes occurring usually after the age of 50 years and as a rule not causing symptoms. [ED NOTE This brief article is of value in calling attention to the variety of lesions to which the intervertebral disk is subject.]

A study of intervertebral spatial changes following extraction of the protruded disk is reported by Graf and Hamby⁷⁷⁵. They introduced a small amount of tantalum powder into the disk sinus in 25 cases. Roentgenographically the sinus appeared either as an elongated slit with an irregular cross section or, less frequently, as a round or oval cavity. Finding that in 1 case the opaque material extended to the

774 Mooney, A. C. Disc Lesions in Relation to Pain, Brit J Radiol **18** 153-157 (May) 1945

775 Graf, C. J., and Hamby, W. B. Roentgenographic Demonstration by Tantalum Powder of Sinuses Resulting from Extraction of Intervertebral Disc Protrusions in J. Roentgenol **53** 157-160 (Feb.) 1945

anterior edge of the vertebral body the authors warn that curettage of the disk must be carried out cautiously in order to avoid penetration of the annulus. Roentgenograms made after several months of normal activity following operation showed no significant alterations. A patient who showed signs of a contralateral lesion postoperatively was reexplored. Histologic observations suggested only mild reaction about the tantalum.

Current conceptions of the clinical syndrome of the ruptured intervertebral disk are presented in a number of articles.⁷⁷⁶ The association of protrusion of the disk with spondylolisthesis is discussed by Meyerding.⁷⁷⁷ Massive extrusion of a lumbar disk is described by Ver Brugghen.⁷⁷⁸ He calls attention to the serious complications which may occur when a ruptured disk is inadequately treated. The extrusion of a large part of a disk may so compress the cauda equina as to cause weakness of a lower extremity with disturbance of urinary function or even to produce a transverse lesion of the cauda equina with paraplegia and incontinence of bladder and rectum. Lesions of this type are sometimes not diagnosed promptly despite the fact that the patient's condition is serious and constitutes a neurosurgical emergency. Ver Brugghen believes that massive extrusions are seen perhaps once in 300 cases of herniated disk. Most of his 9 patients gave a "cogwheel" history in which the picture developed in successive short acute episodes over a considerable period. He discusses the differential diagnosis in 8 cases in which operation was performed. The results were excellent in 1 case, good in 1 and fair in 6. One patient continued incontinent after three and one-half years and another had a persistent paraplegia and was confined to a wheel chair two and one-half years after operation.

The year's articles on the diagnosis of protrusions of the intervertebral disk include clinical analyses and statistical reports of myelographic observations. Munro⁷⁷⁹ discusses the characteristic symptoms and signs. In a review of 177 laminectomies for suspected lesions of the

776 Bradford, F. K. El problema del disco intervertebral en la marina de guerra, Rev. radiol. y fisioterap. **12** 37-44 (May-June) 1945 Larson C. B. Medical Progress Orthopaedic Surgery Problem of Intervertebral Disk New England J. Med. **232** 137-139 (Feb 1) 1945 Swett P. P. A Note on Serruer Bickache and Intervertebral Disks, Connecticut M. J. **9** 701-702 (Sept.) 1945 Walker, E. Intervertebral Disc Lesions General Discussion and Consideration of Treatment in Military Service South M. J. **38** 832-834 (Dec.) 1945 Young J. H. Intervertebral Disk Disease New Syndromes and New Concepts, M. J. Australia **2** 234-245 (Aug 25) 1945

777 Meyerding H. W. Protrusion de los discos intervertebrales en los casos de espondilolistesis. Mediama Mexico **25** 342-349 (Aug 25) 1945

778 Ver Brugghen, A. Massive Extrusions of Lumbar Intervertebral Disc Surg. Gynec. & Obst. **81** 269-277 (Sept.) 1945

779 Munro D. Diagnosis of Posterior Herniation of Lumbar Intervertebral Disk. New England J. Med. **232** 149-150 (Feb 9) 1945

disks Burns and Young⁷⁸⁰ describe a "tension test" which they found useful in differential diagnosis. They raise the patient's affected leg with the knee straight until pain is produced, then flex the knee just enough to relieve the pain, persistence of pain suggests that there is a lesion of the hip. The head is then flexed on the chest, return of pain indicates a lesion of the back. Further flexion of the knee will then relieve the pain of an intraspinal lesion by releasing tension on the meninges continued pain is thought to indicate a lesion outside of the spinal canal.

Fincher,⁷⁸¹ in a discussion of the neurosurgical aspects of lumbar and sciatic pain with especial reference to differential diagnosis, points out that the outstanding diagnostic groups consist of the protrusions of the intervertebral disk, the tumors of the spinal cord and the compensation neuroses. He describes the differential diagnosis of each of these entities with reference to the history, physical examination and roentgenograms and myelograms.

Norlen⁷⁸² has published a detailed analysis of the value of neurologic symptoms in localizing herniations of the lumbar disk. In a study of 37 verified cases of rupture of the disk published in 1942 but not available previously for review, Friberg⁷⁸³ found an average concentration of total proteins of 60 mg per hundred cubic centimeters, a low globulin-albumin quotient and little or no increase of cells in the cerebrospinal fluid.

Four papers on myelography are in agreement in pointing out the diagnostic value of myelograms and in advocating "pantopaque" (a mixture of ethyl esters of isomeric iodophenyl undecylic acids) as the most desirable contrast medium. Echlin, Ivie and Fine⁷⁸⁴ think that "pantopaque" has made myelography a simple, justifiable, and reasonably accurate procedure. Peacher and Robertson,⁷⁸⁵ in a well documented study, found the accuracy of myelographic diagnosis to be 96.7

780 Burns, B. H. and Young, R. H. Protrusion of Intervertebral Disk, *Lancet* 2: 424-427 (Oct 6) 1945

781 Fincher, C. F. Neurosurgical Aspects of Lumbar and Sciatic Pain, *J. M. A. Georgia* 34: 149-154 (Aug) 1945

782 Norlen, G. On Value of Neurological Symptoms in Sciatica for Localization of Lumbar Disc Herniation. Contribution to Problem of Surgical Treatment of Sciatica, *Acta chir Scandinav* (supp 95) 91: 1-96, 1944

783 Friberg, S. Ueber Untersuchungen der Eiweisskonzentration im Liquor bei lumbalen Bandscheibenprolapsen, *Acta chir Scandinav* 87: 128-137, 1942

784 Echlin, F. A., Ivie, J. M., and Fine, A. Pantopaque Myelography as Aid in Pre-Operative Diagnosis of Protruded Intervertebral Disks. Preliminary Report, *Surg Gynec & Obst* 80: 257-260 (March) 1945

785 Peacher, W. G., and Robertson, R. C. L. Pantopaque Myelography Results, Comparison of Contrast Media and Spinal Fluid Reaction, *J. Neurosurg* 2: 220-231 (May) 1945

per cent Soule, Gross and Irving⁷⁸⁶ think myelography should be done in nearly every case of pain in the lower part of the back with sciatic radiation when operation is contemplated. Arbuckle, Shelden and Puden⁷⁸⁷ recommend routine "pantopaque" myelography as an aid in the diagnosis and localization of protruded disks and in ruling out tumors of the spinal cord, the meninges and the cauda equina.

The treatment of the patient with a ruptured disk has been outlined by Key⁷⁸⁸. Noting that the severity of the symptoms and signs varies greatly in different patients and at different times in the same patient he divides the patients therapeutically into three categories ambulant, bed and operative groups. The ambulant patients are treated by support of the lower part of the back, manipulation, stretching of the lower part of the back, correction of body mechanics by exercise a hard flat bed, administration of vitamin B, weight correction administration of salicylates and change of occupation if necessary. Bed patients whose symptoms are so severe that they are unable to carry on their daily routine, are treated in similar fashion and returned gradually to activity. If conservative treatment proves unsatisfactory if the patient is unrelieved or is intolerant of his symptoms and demands relief by surgical treatment or if he has a long history of disability which has not responded to treatment elsewhere, operative treatment is considered. Key thinks that the intact spine should not be fused after the removal of a protruding intervertebral disk and reserves fusion for those patients with long-continued chronic backache in whom the roentgenograms reveal a collapsed disk and in whom no pressure on the nerve roots is found and relieved at operation. Key does not use bone chips over the open spinal canal after the ligamentum flavum has been removed but reinforces the fusion with a notched plate graft taken from the posterior portion of the wing of the ilium. He states that the results of operation for lesions of the intervertebral disks have not been so uniformly successful in his hands as he would wish and analyzes briefly the probable causes of failure. He believes that pain in the lower part of the back with or without sciatica should be treated conservatively and that operative removal of the disk should be reserved for those patients who do not respond to conservative therapy. He considers the removal of ruptured intervertebral disks a sound procedure if the cases are properly selected.

786 Soule A B Jr, Gross S W and Irving J G. Myelography by Use of Pantopaque in Diagnosis of Herniation of Intervertebral Discs. Am J Roentgenol **53** 319-340 (April) 1945.

787 Arbuckle R K, Shelden C H and Puden R H. Pantopaque Myelography. Correlation of Roentgenologic and Neurologic Findings. Radiology **45** 356-369 (Oct) 1945.

788 Key, J A. Conservative and Operative Treatment of Lesions of Intervertebral Discs in Low Back Surgery. **17** 291-303 (July) 1945.

Kirstein⁷⁸⁹ reports a follow-up study of 49 patients who had sciatic pain and roentgenographic evidence of a space-restricting lesion in the spinal canal [ED NOTE Kirstein's statistics, which suggest more favorable results in the 25 patients who were treated by operation, are of little value because of the too brief follow-up period of from one-half to three years]

A study of the end results of the combined operation of excision of the disk herniation and lumbosacral arthrodesis was published by Ghormley Love and Young⁷⁹⁰ in 1943 but has not been reviewed in previous editions of the "Progress in Orthopedic Surgery." Of a series of 72 cases the results after a follow-up period of from one to four years were good in 46 patients fair in 18 and poor in 8. In addition to the herniated disk certain of these patients had spondylolisthesis, spondylosis sacralization, osteoarthritis, sacroiliac arthritis or multiple, recurrent or thinned disks.

Marble and Bishop⁷⁹¹ have analyzed the results of operations on intervertebral disks in a series of 92 industrial cases and have compared them with the results in nonindustrial cases. The proportion of favorable results, less than 50 per cent, is appreciably lower in the industrial cases. The authors point out the greatly increased financial outlay required for operative treatment and for compensation of the patient with an unfavorable outcome following operation. As would be expected, the statistics show that supplementary fusion of the lower part of the back is a less desirable procedure in industrial cases than in nonindustrial [ED NOTE This may be particularly true when the results are evaluated over a relatively short follow-up period]

Poppen⁷⁹² reviews a series of 400 cases of herniated intervertebral disk verified by operation. He believes that the patient who has sciatica and minor back difficulties and whose roentgenograms show no changes in the bone should only have the disk removed, he thinks that the patient who has predominant pain in the back, definitely abnormal facets and instability of the back and who must do hard manual labor should have removal of the degenerated cartilage and fusion. Complete relief of pain in the back and sciatic pain was obtained in 65 per cent of the cases and complete relief of sciatica in 90 per cent. Five per cent of the patients were unrelieved.

789 Kirstein L. An After-Examination of Operated and Non-Operated Cases with Clinical Symptoms of Herniated Disc, *Acta med Scandinav* **120**:93-106, 1945.

790 Ghormley R K, Love, J G, and Young, H H. Combined Operation in Low Back and Sciatic Pain, *Am Acad Orthop Surgeons, Lect*, 1943, pp 120-125.

791 Marble H C and Bishop W A. Intervertebral Disk Injury Analysis from Industrial Standpoint, *J Indust Hyg & Toxicol* **27**:103-109 (April) 1945.

792 Poppen J L. Herniated Intervertebral Disk. Analysis of Four Hundred Verified Cases, *New England J Med* **232**:211-215 (Feb 22) 1945.

Poppen also calls attention to 6 patients who had massive rupture of a disk attended by sudden complete paraplegia. In 2 of these cases paralysis developed immediately after manipulation by osteopaths and in 2 it was apparent on awakening from anesthesia after manipulation by a competent orthopedist. Many weeks or months elapsed before complete function returned [ED NOTE Although this complication does not occur frequently, its gravity makes routine manipulation advisable]. A rare complication of operative removal of the disk an arteriovenous fistula between the right common iliac artery and the inferior vena cava is reported by Linton and White.⁷⁹³

Spondylolisthesis—The number of articles on spondylolisthesis suggests an increased interest in this subject. Buus⁷⁹⁴ published in 1943 a detailed discussion of spondylolysis and spondylolisthesis which has not been available for review in previous editions of the "Progress in Orthopedic Surgery." Of 27 reported cases 20 were observed for from one to twenty-four years. No relationship between trauma and the degree of slipping was demonstrable. The spinal canal was found to be of normal width in cases of mild slipping and only slightly narrowed in the presence of severe slipping. Symptoms, signs and methods of treatment were reviewed. More recently Walker⁷⁹⁵, finding 52 cases of spondylolisthesis in 12,000 Canadian recruits, has discussed the subject with particular reference to the physical signs.

Meschan⁷⁹⁶ describes a method of measuring the degree of spondylolisthesis by means of lines drawn on the lateral roentgenogram. Using this method for comparison of the roentgenographic findings with the patient in various positions, he was able to demonstrate instability at the level of the spondylolisthesis in 7 of 41 patients.

Meyerding⁷⁹⁷ has published in the Mexican literature an article on the protrusion of intervertebral disks in spondylolisthesis. The belief of Dandy⁷⁹⁷ that the symptoms encountered in spondylolisthesis are the results of lesions in disks at other levels of the spine is not shared by most orthopedic surgeons.

793 Linton R R and White P D Arteriovenous Fistula Between the Right Common Iliac Artery and the Inferior Vena Cava Arch Surg 50 6-13 (Jan) 1945

794 Buus C F P On Spondylolysis and Spondylolisthesis Acta orthop Scandiv 14 1-96, 1943

795 Walker J A I Physical Signs of Spondylolisthesis J Canad Med Serv 2 478-482 (May) 1945

796 Meschan I Spondylolisthesis A Commentary on Etiology and an Improved Method of Roentgenographic Measurement and Detection of Instability Am J Roentgenol 53 230-243 (March) 1945

797 Dandy W L Treatment of Spondylolisthesis J A M A 127 157-159 (Jan 20) 1945

Hamblin⁷⁹⁸ describes a case of extreme reversed lumbar spondylolisthesis attended by spastic paraplegia. He states that this congenital abnormality is exceedingly rare. Lombard⁷⁹⁹ has written on congenital lumbosacral luxation.

For the treatment of spondylolisthesis and laminar defects, Bosworth⁸⁰⁰ advocates the use of a "clothespin" or H-shaped graft taken from the ilium or the tibia and mortised about the spinous processes at each end of the fusion area. He states that such grafts should always be supplemented by strips of iliac bone.

Congenital Lumbosacral Anomalies—Fischer and Vandemark⁸⁰¹ present the case histories and roentgenograms of 2 patients who had sagittal cleft or butterfly vertebrae, a rare congenital anomaly which may affect the lumbar part of the spine. This division of a vertebral body into lateral halves by an intervening sagittal cleft was described one hundred years ago by von Rokitansky. Vertebrae with sagittal clefts have been associated with other malformations of vertebrae and ribs. Pain may or may not be present in the back. Treatment consisting of limitation of activity, avoidance of heavy lifting and the use of a back support may be indicated.

McMaster⁸⁰² reports a case of unilateral hypoplasia of the lumbosacral articular processes and associated neural arch of the fifth lumbar vertebra. The patient's pain in the lower part of the back and the thigh was on the side opposite that of the anomaly. McMaster suggests that this patient may have had two primary centers of ossification for the affected half of his fifth lumbar neural arch and that of these the center for the posterior portion may have been hypoplastic.

An operation for stabilization of the asymmetrically sacralized lumbosacral junction has been described by Elo⁸⁰³.

798 Hamblin, E. H. T. Reverse Spondylolisthesis, *Brit J Surg* **32** 536 (April) 1945.

799 Lombard P. Le spondylolisthesis. Luxation congenital lombo sacrée, l'hypothétique glissement de la 5^e lombaire, *Afrique franç chir* **1** 62-63 (March) 1943.

800 Bosworth, D. M. Clothespin Graft of the Spine for Spondylolisthesis and Laminal Defects, *Am J Surg* **67** 61-67 (Jan.) 1945.

801 Fischer, F. J., and Vandemark, R. E. Sagittal Cleft (Butterfly) Vertebra, *J Bone & Joint Surg* **27** 695-698 (Oct.) 1945.

802 McMaster, P. E. Unilateral Hypoplasia of Lumbosacral Articular Processes Case Report, *J Bone & Joint Surg* **27** 683-686 (Oct.) 1945.

803 Elo, R. Stabilizing Operation for Asymmetrical Sacralization, *Acta chir Scandinav* **92** 86-98 1945.

(To Be Continued)

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MECHANISM OF ACUTE ABDOMINAL DISTENTION

Some Observations

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INTRODUCTION

THE STIMULUS for this study evolved in part from an unusual case of acute, massive pneumoperitoneum occurring in a child after perforation of an ileal ulcer opposite the neck of a Meckel diverticulum.¹ The extreme abdominal distention with encroachment on the thorax, as shown in figure 1, was deflated by paracentesis, and yet at the time of the operation, less than one hour later, the distention had returned to its original size and the respiratory rate had increased to 45 per minute.

Where did such a large volume of gas come from and how did it accumulate so quickly? The outstanding work of Wangensteen, Hibbard and Rea² and Singleton and co-workers³ has established atmospheric air as the major source of gas in distention secondary to acute intestinal obstruction. It would seem that exogenous air must also have been the predominant source in the case cited, for it is almost inconceivable that

Reid at the fourth annual meeting of the Central Surgical Association, Chicago, Feb 22, 1947

From the Departments of Physiology and Surgery, Northwestern University Medical School and Wesley Memorial Hospital, Chicago

1 Maddock, W G, and Coventry, M B. A Perforated Ulcer of the Ileum Opposite a Meckel's Diverticulum, *Surg., Gynec. & Obst.* 73:105, 1941.

2 Hibbard, J S, and Wangensteen, O H. Character of the Gaseous Distention in Mechanical Obstruction of the Small Intestine, *Proc. Soc. Exper. Biol. & Med.* 31:1063, 1934. Hibbard, J S. Gaseous Distention Associated with Mechanical Obstruction of the Intestine, *Arch. Surg.* 33:146 (July) 1936. Wangensteen, O H, and Rea C. L. The Distention Factor in Simple Intestinal Obstruction, *Surgery* 5:327, 1939.

3 Singleton, A O, Rogers, F, and Houston, F G. The Problem of Intestinal Gases Complicating Abdominal Surgery, *Ann. Surg.* 115:921, 1942.

fermentation or diffusion could produce so much gas in such a short time. But how could air enter the abdomen so rapidly? The generally accepted explanation would be by air swallowing, which theoretically might have supplied such a volume in a comparatively short period of time. However, repeated swallowing was not observed. Rather it appeared that the child had literally pumped himself up. One of us (A.C.I.) has observed this phenomenon in 2 dogs under light ether.



Fig 1—Massive pneumoperitoneum in a child following perforation of an ileal ulcer. Note marked distention with extreme encroachment on the thorax.

anesthesia while the gallbladder was being artificially distended. Similarly, Alvarez,⁴ referring to several instances in which he had observed acute dilatation of the stomach in experimental animals, stated, "In some instances it was due to a peculiar type of powerful, sighing, respiratory movement which soon pumped the stomach full of air."

⁴ Alvarez, W. C. An Introduction to Gastroenterology, New York, Paul B. Hoeber, Inc., 1940 pp 563-588

The role of true air swallowing in slowly developing distention was demonstrated by the early work of Kantor and Marks,⁵ who showed by combined auscultatory and roentgenographic means that air is actually swallowed in conjunction with the ingestion of food and drink. However, in rapid distention, usually involving larger volumes of gas, frequent, voluntary swallowing is not commonly reported, though one would expect it to be if swallowing were an important factor in the distention mechanism. In the literature only an article by McIver Benedict and Cline⁶ states the number of observed, true swallows. In 3 surgical cases they counted one hundred and fifteen, sixty-seven and forty-four swallowing movements respectively during the induction of ether anesthesia, though the volume of gas recovered from these particular patients was not stated. In another series of patients the average volume of gastric gas "swallowed" between the induction of anesthesia and completion of the operation was 145 cc. Subsequently, Davis and Hansen⁷ inserted a Levine tube into the stomachs of 53 patients pre-operatively and found that an average of 126 cc of gas accumulated in the stomach during the operation. No mention was made of observations on swallowing by these patients.

Such a paucity of data by no means constitutes proof of the non-existence of air swallowing as a factor in acute abdominal distention nor does it in any way lessen the strong evidence favoring atmospheric air as the chief source of the distending gas. Granted that the air comes down through the esophagus, the question arose whether or not any other mechanism than air swallowing could account for its entry. A review and investigation of other conditions in which atmospheric air can accumulate in the upper part of the gastrointestinal tract seemed warranted. The most pertinent literature concerned acute dilatation of the stomach, air sucking and esophageal speech. These will be commented on and the results of experiments which developed will be reported.

REVIEW OF THE LITERATURE

A. Acute Gastric Dilatation—Rokitansky,⁸ in 1842, first described the postmortem observations in a case in which "the stomach filled the entire abdomen," and this is considered the first report of acute dilatation.

⁵ Kantor, J. L. A Study of Atmospheric Air in the Upper Digestive Tract. Am. J. M. Sc. 155:829, 1918. Kantor, J. L. and Marks, I. A. A Study of Intestinal Flatuscence, Ann. Int. Med. 3:403, 1929.

⁶ McIver, M. A., Benedict, E. B., and Cline, J. W. Jr. Post Operative Gaseous Distention of the Intestine. Experimental and Clinical Study. Arch. Surg. 13:588 (Oct.) 1926.

⁷ Davis, H. H., and Hansen, T. M. Investigation of the Cause and Prevention of Gas Burns Following Abdominal Operation. Surgery 17:492, 1945.

⁸ von Rokitansky, C. Handbuch der speziellen pathologischen Anatomie ed. 3, Vienna, Braumüller u Seidel 1842 vol. 3 p. 172.

of the stomach. Thirty years later Hilton Fagge⁹ recorded the classical clinical description of vomiting, tremendous gaseous and fluid distention of the stomach and collapse. Subsequently epigastric pain, abdominal tenderness, constipation, thirst and oliguria were found to be associated symptoms of variable severity.

Acute dilatation of the stomach is customarily a complication of some preexisting medical or surgical problem. In 90 per cent of the cases vomiting is the presenting symptom,¹⁰ and in surgical patients this may easily be mistaken for the usual postoperative emesis. Characteristically regurgitant, the vomiting amounts to a sort of overflow of a thin, brownish, nonfeculent fluid, often voluminous but affording little relief to the patient.

The most prominent sign of the disease is the tremendous gastric distention. Concerning the volumes involved there are few figures available. Usually only such descriptive terms as "stomach greatly distended, chiefly with gas"¹¹ or "stomach enormously dilated and reaching down nearly to the pubis"¹² have been found. Laffer¹⁰ reported a case in which the distention was so great that the body could not be placed in a casket. When a trocar was passed into the stomach "a great quantity of gas and a quart of milky fluid escaped" (compound spirit of ether N F had been administered). Three cases were found in which the gastric volume could be calculated from reported postmortem measurements of the stomach. In a case reported by Luckett¹³ the size of the stomach was 17 by 10 by 7 inches (43.2 by 25.4 by 17.8 cm.), which represents a volume of at least 7,500 cc. More conservative were the postmortem measurements of the stomach in 2 of Moore's¹⁴ cases, from which the volumes were calculated to be 3,000 cc and 2,600 cc respectively. Thomas and Harper¹⁵ recently reported a case in which they aspirated 2,000 cc. of gas.

The rapidity with which enormous acute gastric dilatation develops has been frequently commented on, but seldom with the desired accuracy. However, 11 cases have been collected in which there were notations

9 Fagge, C. H. Acute Dilatation of the Stomach, Guy's Hosp Rep **18** 1, 1873.

10 Laffer, W. B. Acute Dilatation of the Stomach and Arterio-Mesenteric Ileus, Ann Surg **47** 390, 1908.

11 Thomson, H. C. Acute Dilatation of the Stomach, New York, William Wood & Company, 1902.

12 Broadbent, W., cited by Thomson.²¹

13 Luckett, W. H. Visible Acute Dilatation of the Stomach During Laparotomy, J A M A **64** 2055 (June 19) 1915.

14 Moore, J. W. Gastromesenteric Ileus, New York, M. J. **105** 544, 1917.

15 Thomas, C. A., and Harper, F. R. Acute Dilatation of the Stomach Following Left-Sided Phrenic Paralysis and Thoracoplasty, J Thoracic Surg **5** 507, 1935.

of the distention time or sufficient data from which it could be roughly estimated. These are shown in table 1, and it is apparent that marked distention occurred within fifteen minutes or less in 8 of the 11 cases.

The alleged factors causing acute gastric dilatation are both numerous and diverse, almost every common medical and surgical condition having been implicated. Borchgrevink,¹⁶ reporting a series of 144 unselected cases, related 44 different predisposing causes. These, with a few additions, are shown in table 2. Sex, race, occupation or environment have not been found to be etiologically significant and no age is exempt, for Behlios¹⁷ saw acute gastric dilatation in a 9 month old baby, while Moore¹⁸ recorded the case of an 86 year old man.

To account for acute dilatation of the stomach many theoretic hypotheses have been proposed, as indicated by the following synonyms:

TABLE 1.—*The Rate of Distention in Acute Dilatation of the Stomach*

Author	Distention Time	Degree of Distention
Doolin ²⁰	"Few minutes"	"Alarming size"
Laffer ¹⁹	Less than one hour	"Greatly distended"
Lee, B. J. Ann. Surg. 63:418, 1916	5 to 15 minutes	"Enormously dilated"
Luckett ²¹	15 minutes	"Tremendous distention"
Mallory, T. B. New England J. Med. 219:160, 1938	Less than two hours	"Tremendous distention"
Maynard, A., Jr. J. A. M. A. 64:146, 1915	5 to 10 minutes	Distended to within three fingerbreadths of the symphysis pubis
Melver ²²	5 minutes	Dilatation
Moorhead, L. L. J. A. M. A. 52:1800, 1909	5 minutes	Distention to midpoint between the umbilicus and pubis
Novak, I. J. A. M. A. 77:81, 1921	"Less than 30 seconds"	"Enormous size"
Richardson, W. G. Brit. M. J. 2:1202, 1913	5 to 10 minutes	Distended
Thomas and Harper ²³	"Within 30 minutes"	"Enormous distention"

commonly employed acute gastroduodenal atony, acute postoperative gastric paralysis, gastroenteroplegia, gastrorrhœa and acute gastromesenteric ileus.

The atonic theory, first mentioned by Brinton in 1859,¹⁶ holds that acute dilatation of the stomach is the result of a reflex disturbance of the extrinsic gastric innervation. This allegedly produces gastric atony, as a result of which gases and fluids ordinarily formed in the stomach and intestines are permitted to accumulate rather than being absorbed.

16 Borchgrevink O. J. Acute Dilatation of the Stomach and its Treatment, Surg., Gynec. & Obst. 16:662 1913.

17 Behlios, D. A. Acute Dilatation of the Stomach Without Asphyxie + Co. Brit. M. J. 1:74, 1903.

18 Brinton, W. Lectures on Disease of the Stomach ed. 1. 1859 pp. 1-111 Churchill & Sons, 1859 pp. 291-300.

or expelled. The significance of atony in permitting the accumulation of large volumes of gastric gas was demonstrated by Kelling¹⁹ and Braun and Seidel,²⁰ who through gastric fistulas artificially distended the stomachs of conscious dogs until eructation occurred. In the same animals under anesthesia or after vagotomy they found that two to three times greater distention could be maintained without eructation. However, such evidence supplies only a negative factor in explanation of the atonic theory, for it stresses loss of tone without offering any proved positive mechanism to account for the distending gas.

TABLE 2.—Reported Causal Factors in Acute Dilatation of the Stomach

Abdominal and Pelvic Operations		
Biliary Tract		
Genital Tract		
Gastrointestinal		
Appendectomy	Oophorectomy	Cesarean section
Bowel anastomosis	Cholecystostomy	Anterior colporrhaphy
Gastroduodenostomy	Drainage of hepatic abscess	Hysterectomy
Gastrojejunostomy		Oophorectomy
Gastrostomy		Perineorrhaphy
Herniorrhaphy		Salpingectomy
Pyloric resection		Uterine fixation
Extra Abdominal Operations		
Urinary Tract		
Nephrectomy	Amputations	Thorax
Nephropexy	Hip joint resections	Phrenicotomy *
Urethrostomy	Osteotomy	Thoracoplasty *
Vagotomy *		
Acute and Chronic Diseases		
Cholecystitis	Maxillary sinusitis	Scarlet fever
Diabetes	Pneumonia	Sciatica
Endocarditis	'Rheumatism'	Tuberculosis
	Typhoid	
Deformities		
Lumbodorsal scoliosis		Spinal tuberculosis
Spondylolisthesis		
Miscellaneous		
Anesthesia (general, spinal, local)		Application of body cast
Childbirth		Abdominal trauma
Fractures		Ureteral catheterization
Puraplegia		Dietary indiscretion

* Added from other sources.

Often cited in support of the atonic theory are the reports of Hartwell,²¹ Carion and Hallion²² and Smith,²³ who claimed to have observed or produced acute dilatation of the stomach by cervical, transthoracic

19 Kelling, G. Ueber den Mechanismus der acuten Magendilatation, Arch f Klin Chir 64:393, 1901.

20 Braun, W., and Seidel, H. Klinisch-experimentelle Untersuchungen zur Frage der akuten Magenerweiterung, Mitt a d Grenzgeb d Med u Chir 17:533, 1907.

21 Hartwell, J. A., in discussion on Moschcowitz, A. V. Gastromesenteric Ileus Following a Cholecystectomy, Ann Surg 55:614, 1912.

22. Carion and Hallion. Dilatation de l'estomac par section des nervos vagues, Bull med, Paris 9:809, 1895.

23 Smith, H. B. Postoperative Acute Dilatation of the Stomach, Boston M & S J 161:529, 1909.

or subdiaphragmatic vagotomy. None of these authors presented sufficient data to permit repetition of their work or proper evaluation of their results. Furthermore, vagotomy has been produced thousands of times in dogs and several hundred times in human beings with only an occasional case of true acute, gaseous, gastric dilatation occurring as a complication,²⁴ though immobility and some degree of gastric atony may be a frequent postoperative finding.

The theory of duodenal obstruction was proposed by von Rokitansky²⁵ in 1861. It stated that acute dilatation of the stomach is nothing more than a high intestinal obstruction occurring in the third portion of the duodenum the obstructing element being the mesentery and superior mesenteric vessels overlying the duodenum as it crosses the spine. Kundrat²⁶ first reported 3 cases which illustrated this type of mechanical obstruction, and subsequently Albrecht,²⁷ Muller,²⁸ Schnitzler²⁹ and others having observed this condition in their own cases, joined in endorsing the theory. Since duodenal obstruction was actually found in only 20 to 25 per cent of cases in which autopsy was performed,³⁰ controversy arose as to whether this was a primary phenomenon or secondary to the gastric distention, which pushed the intestines into the pelvis, thereby tensing the mesentery and the vessels crossing the duodenum. L. R. and C. A. Dragstedt³¹ by obstructing the third portion of the duodenum in 5 dogs showed that though severe toxic symptoms developed within seventy-two hours the stomachs remained small. They concluded that primary duodenal obstruction did not cause acute dilatation of the stomach, but proposed that if duodenal obstruction occurred secondary to gastric distention it could account for the severe toxic symptoms and collapse frequently seen.

²⁴ Jones, C. M., in discussion on Grimson, K. S., Russin, J. M. and Hollander, F. Discussion on Symposium on Peptic Ulcer with Particular Reference to Vagotomy. *Gastroenterology* 7: 615, 1946.

²⁵ von Rokitansky, C. *Lehrbuch der pathologischen Anatomie*, ed. 3 Vienna W. Braumüller, 1861 vol. 3.

²⁶ Kundrat Ueber eine seltene Form der inneren Incarceration Wien med Weltscr. 41: 352, 1891.

²⁷ Albrecht, P. A. Ueber arterio-mesenterialen Darmverschluss an der Duodeno-Jejunalgrenze und Seine ursächliche Beziehung zur Magenverwirting. *Virchows Arch f path Anat* 156: 285, 1899.

²⁸ Muller, P. Ueber akute postoperativa Magendilatation hervorgerufen durch arterio-mesenteriale Duodenal-Kompression. *Deutsche Ztschr f Chir* 56: 496, 1900.

²⁹ Schnitzler, I. Ueber mesenteriale Darmnecrose. Wien. klin. R. 11: 579, 1895.

³⁰ Doolin, W. Acute Dilatation of the Stomach But J. Surg. 6: 125, 1919. Lassier³⁰

³¹ Dragstedt, L. R. and Dr. Geddi, C. A. Acute Distension of the Stomach. J. A. M. A. 79: 612 (Art. 10) 1922.

In 1912, Woodyatt and Graham³² advanced the theory that acute dilatation of the stomach is due to gastric secretion of gas, the result of interference with oxidative processes in the wall of the stomach as a sequela of local impairment of blood supply, general asphyxia or poisoning. The theory was based on the early work of Schierbeck,³³ who reported high tensions of carbon dioxide in the stomach during the height of digestion. However, this later work has since given way to the conclusive observations of McIver, Redfield and Benedict³⁴ that the tensions of gases of the alimentary tract tend to approach those of the blood, obeying the laws of physical diffusion.

It seems apparent from the foregoing review that the mechanism of acute dilatation of the stomach still remains obscure and confused. Most of the contributions to the subject have been efforts to explain the cause of the disease, while careful observations that might have given a clue to the source of the gas and its mode of transport to the stomach have been minimal. In few of the cases reviewed was air swallowing even suggested as the means of accumulation of gas. Rather, one keen observer, Luckett,¹⁸ reporting a case in which acute distension occurred during surgical treatment, stated "I could distinctly feel and hear large gulps of air entering the stomach, and hear a noise in the throat, yet the patient was not swallowing, that is, the thyroid cartilage was apparently still and there was no visible motion in the throat." Similarly, McIver³⁵ recorded 3 cases of acute dilatation of the stomach during surgical treatment in which he stated that the occurrence of swallowing was not noted either by himself or by the anesthetist. Since many reported cases of acute dilatation of the stomach have occurred during administration of a general anesthetic when the swallowing reflex might reasonably be expected to have been largely abolished, further doubt is cast on the role of ordinary swallowing as an important factor in the mechanism of this disease.

Though not ordinarily considered of significance in the mechanism of acute gastric dilatation, the possible importance of abnormal respiration has been suggested. Mention has been made of Alvarez's⁴ comment of having observed peculiar, powerful respiratory movements pump the stomach full of air, and Klempner³⁶ in reviewing the caus-

32 Woodyatt, R T, and Graham, E A Alimentary Respiration, Ohio State M J 8 407, 1912

33 Schierbeck, N P Skandinav Arch f Physiol 3 437, 1892

34 McIver, M A, Redfield, A C, and Benedict, E B Gaseous Exchange Between the Blood and the Lumen of the Stomach and Intestines, Am J Physiol 76 92, 1926

35 McIver, M A Acute Dilatation of the Stomach Occurring Under General Anesthesia, Ann. Surg 85 704, 1927

36 Klempner, D The Cause of Acute Dilatation of the Stomach, Illinois M I 68 159, 1935

ation of this disease said "A common factor in all cases of acute dilatation of the stomach associated with surgery is a disturbed respiratory mechanism." Specific references to the character of the respiration in acute gastric dilatation are seldom made, though in Thomson's³ series of 44 cases 9 presented respiratory abnormalities as follows pneumonia and/or pleurisy 4, pulmonary edema 2, empyema 1, marked dyspnea 1 and hiccups 1.

B. Air Sucking—Weissgerber³⁷ credited Kehrer in 1877 with first suggesting that air could be "sucked" into the stomach. Though few details are reported, Kehrer is said to have inserted a small rubber tube through the esophagus into the stomach of newborn infants and with an attached mercury manometer recorded subatmospheric intragastric pressures during the inspiratory phase of respiration. Actual figures were not recorded, but the author concluded that such "respiratory sucking" accounted for the free gas in the stomach and intestines of the newborn. Studying 7 newborn infants, Paine and Ness³⁸ roentgenographically demonstrated gas in some part of the upper gastrointestinal tract within fifteen minutes after birth. Dillon,³⁹ in an article on "The Respiratory Function of the Digestive Tract as the Basis of a Roentgenographic Life Test," stated that carefully verified roentgenologic investigations "prove" that air may penetrate into the stomach without any gulping movement, such "stomach respiration" accounting for the air bubble ordinarily seen in the cardiac end of the stomach.

Wylle⁴⁰ in 1895 wrote an exceedingly interesting article carefully describing the mechanism of "air sucking," whereby air could be introduced into the upper part of the alimentary tract without swallowing. After studying 3 students who performed this act voluntarily he related the procedure briefly as follows. Elevate the chin and extend the neck to pull the larynx forward, then make an inspiratory effort against a closed glottis. By direct laryngoscopic examination of the upper end of the esophagus during the act he observed that this position produced a small opening in the normally closed sphincter at the pharyngoesophageal junction, referred to as the superior esophageal sphincter.⁴¹

³⁷ Weissgerber, P. Ueber den Mechanismus der Ruhe und Erregung des Lufteintritts in den Magen. *Neueborener Perl. Un. Webersc.* 15: 521, 1878.

³⁸ Paine, J. R., and Ness, C. F. Observations on the Distribution and Transport of Gas in the Gastrointestinal Tract of Infants and Young Children. *Am. J. Sc.* 14: 291, 1932.

(this structure will be described later) With each inspiratory effort against a closed glottis air readily entered the esophagus and was belched during expiration or passed on into the stomach if eructation was suppressed Such air sucking is known to be a fairly common accomplishment of adolescent boys, who learn the procedure to become the most proficient "belcher" in their group Such persons will be referred to in this article as air suckers

Intake of air during this act is apparently due to the negative pressure developed during inspiration, for the esophagus is subject to the changes in pressure that develop in the intrapleural space⁴¹ Though negative intrapleural and thus intraesophageal pressures as low as minus 40 mm of mercury have been shown to develop during inspiration against an obstruction,⁴² McIver³⁵ demonstrated in anesthetized cats that the negative intraesophageal pressure developed during unobstructed inspiration could "aspirate" air through a rigid tube passed into the esophagus When a one way valve prevented its escape on expiration the air accumulated in the stomach, having been propelled from the esophagus by peristalsis or an esophageal-gastric pressure gradient To account for a possible valvelike action in man McIver postulated that the soft palate or the tongue might drop back, obstructing the escape of air from the esophagus on expiration However, it seems apparent that such an obstruction would also interfere with pulmonary expiration, resulting in elevation of the intrapleural and consequently the intraesophageal pressure, which would tend to force the air out of the esophagus As will be brought out later, the possibility of a valvelike action of the superior esophageal sphincter seems a more likely explanation, for it would obstruct the escape of intraesophageal air without interfering with pulmonary expiration

C Esophageal Speech—Continued search for knowledge of any condition in which air enters the upper alimentary tract without swallowing led to a consideration of the subject of esophageal speech After a laryngectomy many patients have been taught to "aspirate" air into the esophagus during inspiration, then eructate it back to produce vibrations of the superior esophageal sphincter, such vibrations being then converted into speech by the oral structures

Morrison⁴³ stated that proficiency in esophageal speech depends on the character of the musculature of the pharyngoesophageal junc-

41 Hevnsius, A Ueber die Grosse des negativen Drucks im Thorax beim ruhigem Athmen, Arch f d. ges Physiol 29: 265, 1882

42 Best, C. H., and Taylor, N. B. The Physiological Basis of Medical Practice ed 4, Baltimore, Williams & Wilkins Company, 1945, pp 297-298

43 Morrison, W. W. The Production of Voice and Speech Following Total Laryngectomy Exercise and Practice for Production of Pseudovoice, Arch Otolaryng 14: 413 (Oct.) 1931

tion (cricopharyngeus muscle) and the ability of the subject voluntarily to relax the superior esophageal sphincter, so that air can be taken in without swallowing. Stetson⁴⁴ has further shown that the part played by the chest in esophageal speech is greater than normal, for the intake of air is dependent on the negative intraesophageal pressure developed during inspiration.

Patients must learn to retain the aspirated air in an esophageal reservoir, otherwise it will be propelled on into the stomach by peristalsis. This was demonstrated experimentally by Quinche⁴⁵ who introduced air into the esophagus in dogs and found that within four to five seconds it had been propelled into the stomach. That this unavoidably occurs in patients being taught esophageal speech was shown fluoroscopically in more than 50 per cent of 100 patients studied by Stern.⁴⁶ Similarly Morrison⁴⁷ stated that in many patients some of the aspirated air "slips into the stomach where it increases the size of the gastric air bubble," while others less satisfactorily used the stomach rather than the esophagus as their air reservoir. It is interesting to note at this point that many ventriloquists are said to utilize esophageal speech for their manikin,⁴⁸ and the German word for ventriloquism, "Bauchredner," is a combination of two words meaning belly speech.

The similarity between the mechanisms of air intake in air sucking and in esophageal speech is apparent. The procedure for the former is described as elevation of the chin and extension of the neck to pull the larynx forward, while making an inspiratory effort against a closed glottis. On the other hand laryngectomized patients being taught esophageal speech, while first learning, are instructed to elevate the larynx bone and "close the tracheal opening with their finger, then attempt to insufflate air into the esophagus during the act of chest expansion."⁴⁹ In both instances the act is dependent on relaxation of the superior esophageal sphincter while a negative intraesophageal pressure is developed by inspiration. It is conceivable that this mechanism, or some modification of it, may occur in acute dilatation of the stomach and other commoner types of acute abdominal distention.

EXPERIMENTAL METHODS AND RESULTS

A Experiments on Animals—The most direct approach to the study of the mechanism involved in acute gastric distention seemed to be to produce this condition in animals, and then to observe and record the factors involved in the process. Taking suggestions from several reports of the intentional and unintentional development of acute distention of the stomach found in the literature, we made attempts to reproduce such results in dogs. The methods employed and the results obtained are briefly recorded in table 3. Since none of the methods employed consistently produced acute distention, only the results of two associated experimental studies will be discussed.

As was previously mentioned, McIver³⁵ produced acute gastric distention in anesthetized cats by inserting a glass tube with a one way valve into the upper part of the esophagus. Since the tube merely overcame or eliminated the action of the superior esophageal sphincter, it became apparent to us that this structure must be the normal obstructing mechanism to the ingress of air into the esophagus without swallowing. Anatomically, in the dog, this sphincter was found to be composed of a well formed mucosal fold with a circular lip directed caudad, as shown in figure 2. This structure was found at the pharyngoesophageal junction at the same level as the transverse fibers of the inferior pharyngeal constrictor muscle, and together the mucosal fold and the constrictor muscle fibers form the superior esophageal sphincter, first described by Killian^{40a} in 1908. Like other sphincters of the alimentary tract it should favor the ingress of matter while preventing the escape cephalad.

In view of these facts it was considered pertinent to determine whether the tone of the superior esophageal sphincter could be decreased sufficiently to allow the ingress of air into the esophagus coincident with the negative intraesophageal pressure developed during inspiration. First, a reflex was sought that might relax the sphincter tone or cause the structure to act as a one way valve. Because of the high incidence of acute distention following abdominal surgical treatment, intra-abdominal stimuli were considered most likely to produce such an effect. Secondly, denervation of the sphincter was performed to determine whether this would reduce its tone and permit entry of air.

1. Effect of Intra-Abdominal Stimuli on Tone of Superior Esophageal Sphincter. In 8 dogs anesthetized with ether a small recording balloon was inserted into the superior esophageal sphincter and attached by a rubber tube to a water manometer which recorded on a revolving kymograph drum. Simultaneously tracings of respiratory and swallowing movements were made. With this arrangement stimulation of the celiac and mesenteric plexuses, splanchnic nerves, sympathetic trunks and celiac artery was carried out with faradic current. In addition,

TABLE 3.—Summary of Attempts to Produce Acute Gastric Distension in Dogs

Procedure	No of Trials	Indication	Result
1. Vagotomy			
a Transthoracic	5	Report of Caron and Hallion ²¹	Failure
(1) Plus phrenicotomy	1	Report of Thomas and Harp ²²	Failure
b Cervical	2	Report of Hartwell ²³	Failure
c Subdiaphragmatic	2	Report of Smith ²⁴	Failure
(1) Plus duodenal obstruction	1	Report of Smith ²⁵	100 cc of gas and 2 ml in 2 hours
(2) Plus intravenous and oral administration of antimony potassium tartrate	2	Report of Braun and Sell ¹⁹	No vomiting no distention
(3) Plus intra abdominal stimuli	1	High incidence of acute distension associated with laparotomy	Failure
2. Gastric vascular ligation	1	Report of Woodyatt and Graham ²²	Failure
3. Duodenal obstruction ("d" portion)	1	Report of Hundrat ²⁶	Small volume of fluid and gas in 24 hours
4. Gastric torsion			
a 90° clockwise	1	Report of Blackburn P. S., and Melvin, D. J. Comp Path. & Therap 64: 189 1944	Failure
b 270° counterclockwise	1	Report of Melvin ²⁷	Failure
5. Intestinal irritation with croton oil			
a In cecum	1	Report of Hedblom C. A., and Cannon W. B. Am J Physiol 118: 604, 1937	Failure
b In ileum	1	Acute distension associated with chemical peritonitis	Failure
6. Irritation of peritoneum with HCl	1	Report of Phillips, O. Proc Soc Exper Biol & Med 1: 60, 1909	Failure
7. Retropertitoneal injection of blood	2	Report of Phillips, O. Proc Soc Exper Biol & Med 1: 60, 1909	Failure
8. Cervical vagal stimulation (Faradic current)			
a Bilateral intact and transected central and distal ends	3	Report of Meltzer S. J., and Auer J. Proc Soc Exper Biol & Med 73: 199-1903	Contraction of esophagus no distention
b Same as (a) with superior esophageal sphincter intubated	3	Report of Meltzer and Auer and of Melvin ²⁸	Contraction of esophagus no distention
9. Ureteral distension	2	Report of Marquison W. Acta Radiol 12: 652, 1931	Failure
10. Intra abdominal stimuli (effect on secondary peristalsis)			
a Distention of gallbladder	2	To determine whether these stimuli would cause secondary peristalsis to transport air	Failure
b Duodenal distension	2		
c Manual manipulation of organs of upper part of abdomen	2		
11. Manually "ball valving" the intubated esophagus			
a Alone	2	Report of Melvin ²⁹	Distension in one-thlrd dogs only
b After subdiaphragmatic vagotomy	2	Report of Melvin ²⁹ plus effect of atony	Appreciable distension in one-thlrd dogs only
c After transthoracic vagotomy	1	Report of Melvin ²⁹ plus effect of atony	Appreciable distension in one-thlrd dogs only
12. Intra abdominal stimuli (effect on tone of upper esophageal sphincter)			
a Distention of gall bladder	1	To determine whether one intra abdominal stimuli would reflexly affect tone of upper esophageal sphincter	Failure
b Duodenal distension	2		Failure
c Trauma of abdominal viscera	2		Failure
d Chemical irritation of peritoneum with 9% alcohol	1		Failure
e Stimulation of superior mesenteric and/or celiac ganglion	1		Failure
f Subdiaphragmatic vagal stimulation	1		

severe trauma to the bowel by tamponade and traction, distention of gallbladder and duodenum with balloons and chemical irritation of the peritoneum with alcohol were tried. Eleven such procedures in 8 dogs did not result in any appreciable change in the tone of the superior esophageal sphincter. In 7 of another series of 17 lightly anesthetized dogs subdiaphragmatic vagal stimulation with moderately intense faradic current produced a short period of apnea followed by hyperpnea, vigorous clonic contractions of the diaphragm and pronounced fluctu-



Fig 2.—Superior esophageal sphincter in the dog. Note that the lip is directed caudad

ations in tone of the superior esophageal sphincter. A typical tracing is shown in figure 3. In 3 instances definite acute gastric distention occurred coincident with this phenomenon, the stomach protruding through the abdominal wound and necessitating release of 250 to 400 cc of gas with a syringe and needle before the stomach could be replaced in the abdominal cavity. Though the source of gas and the actual mechanism involved in its transport could not be definitely ascertained in these instances, true swallowing was not seen to occur. The rate of accumulation of gas in these dogs, thirty to sixty seconds, favors an exogenous

source, and the concurrent powerful respiratory excursions seemed to be an important part of the process.

That the upper esophageal sphincter acted as a one-way valve is unlikely, for kymograms of this phenomenon made on a rapidly revolving drum showed increased sphincter tone during inspiration and relaxation during expiration. It was considered that the recorded activity of the sphincter might merely be secondary to vigorous respiratory excursions but in 2 instances the number of fluctuations in sphincter tone did not correspond with the number of deep respirations. Furthermore tachypnea produced by intravenous injection of 1 cc of urea per kilogram of body weight and hyperpnea induced by the intravenous injection of 15 cc of dilute hydrochloric acid failed to produce comparable fluctuations in the tone of the esophageal sphincter.

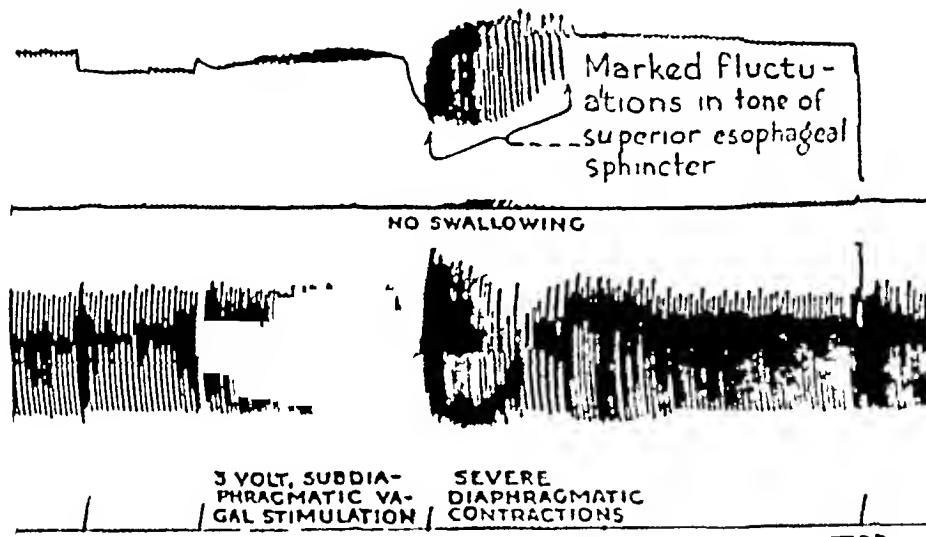


Fig. 3.—Water manometer tracing showing the effect of subdiaphragmatic vagal stimulation on activity of superior esophageal sphincter. Top tracing: activity of esophageal sphincter. Second tracing: record of swallowing. (Small elevations do not represent swallows but are due to movement of recording equipment as a result of violent respiratory excursion.) Third tracing: response to Pottoni stimulus.

surgical transection of all visible nerves in the vicinity of the hypopharynx and upper end of the esophagus. This dog was unable to swallow food or water on recovery from the operation, and during the observed period of six days no distention developed.

Experimental work on esophageal innervation now being carried out by Hwang, Grossman, and Ivy at the University of Illinois has revealed that a small nerve, apparently arising just above the ganglion nodosum of the vagus, supplies the main motor innervation to the cervical part of the esophagus in the dog. Its control over the superior esophageal sphincter has not been established, but experiments are contemplated to determine the effect of bilateral transection of this nerve.

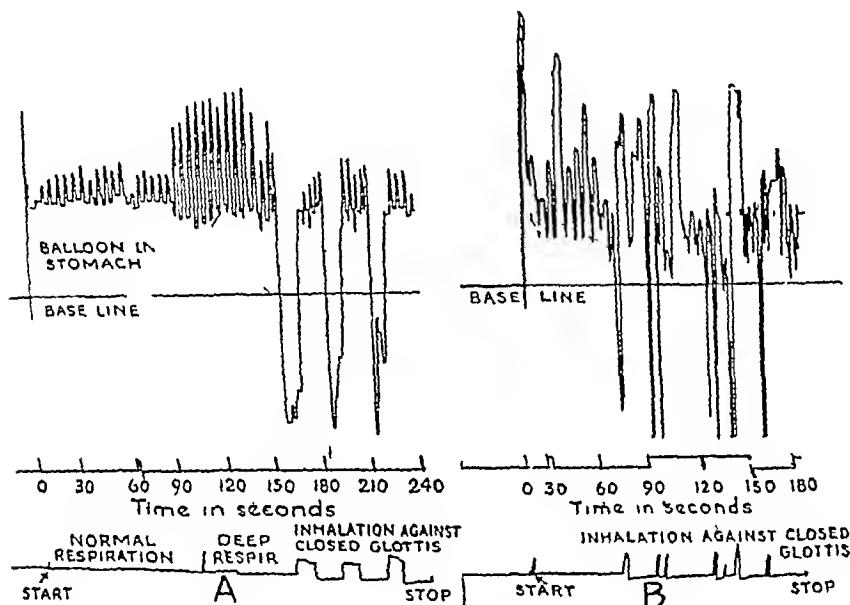


Fig 4.—A, bromoform manometer tracing of negative intragastric pressure developed during inspiration against a closed glottis. B, bromoform manometer tracing (tube in lower part of esophagus) of negative intraesophageal pressure developed during inspiration against a closed glottis.

B Experiments on Human Beings—The inability to produce acute distention consistently in dogs nullified any attempts to determine the mechanism by this means. On the basis of recorded descriptions of air sucking it seemed relevant to study the factors involved in this act to determine their applicability to the mechanism of acute distention.

1 Intraesophageal and Intragastric Pressures Developed During Inspiration Against a Closed Glottis First, the intragastric pressure developed during inspiration against a closed glottis was determined. Each of 7 subjects swallowed a small Levine tube until the attached recording balloon lodged in the cardiac end of the stomach. The external end of the tube was then attached to a bromoform manometer and the balloon inflated with 30 to 40 cc of air. After a short normal recording

on a slowly revolving kymograph the seated subject was first directed to make several inspiratory efforts against a closed glottis. Then in 3 subjects the balloon was deflated and withdrawn to the level of the lower part of the esophagus, where it was fixed and reinflated with 5 to 10 cc of air. After a short control period the subjects again made inspiratory efforts against a closed glottis while additional tracings were made. Typical tracings are shown in figure 4, while the summarized results converted to water pressure are recorded in table 4. It is apparent from the results that inspiration against a closed glottis converted a normally positive intragastric pressure of + 2 to + 16 cm of water² to an average negative pressure of — 29.6 cm of water. Similarly, the same act markedly increased the normally negative intraesophageal pressure from — 6 cm to — 31.1 cm of water.

2 Volumes of "Aspirated" Air (a) During air sucking. The volume of air that could be "aspirated" per sucking effort by 5 subjects

TABLE 4.—*Negative Pressures Created During Inspiration Against a Closed Glottis*

Subject	Intraesophageal		Subject	Intragastric	
	Number of Efforts at Inspiration	Average Pressure Cm H ₂ O		Number of Efforts at Inspiration	Average Pressure Cm H ₂ O
1	4	+25.0	1	4	+2.0
2	7	+33.0	2	7	+1.0
3	3	+2.6	3	5	+4.2
			4	5	+1.5
			5	5	+2.6
			6	5	+1.5
			7	5	+2.6

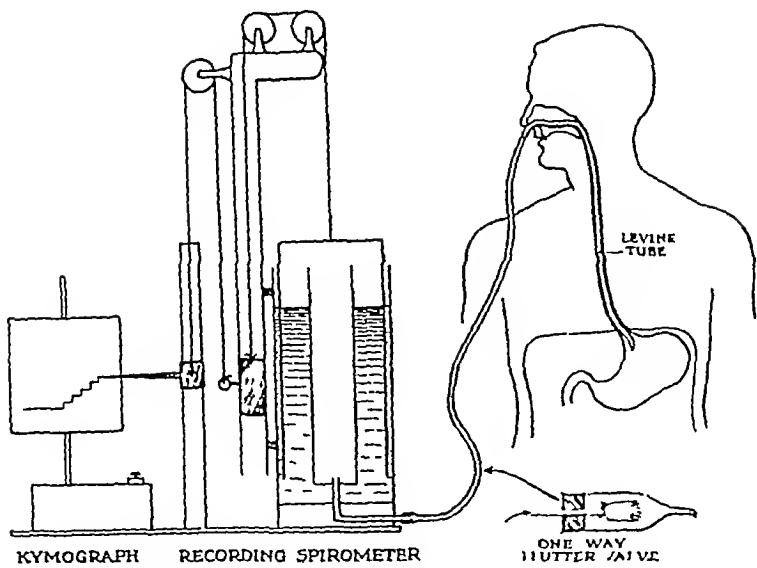


Fig 5.—Apparatus utilized in recording volumes of gastric gas

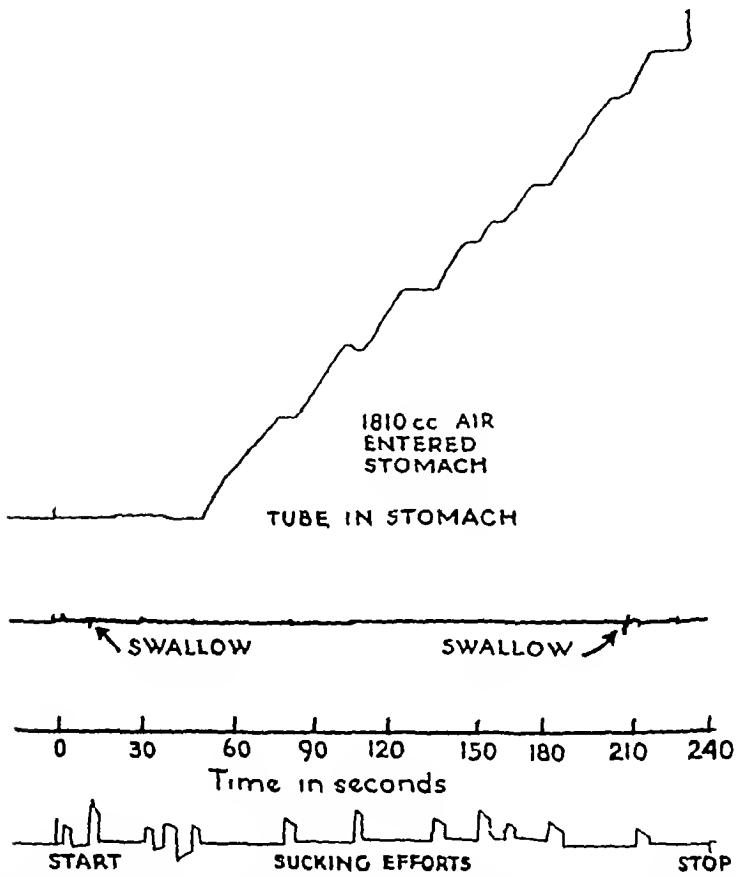


Fig 6.—Recording spirometer tracing of air "aspirated" into the stomach by air sucking

(b) During inspiration against a closed glottis. Generally, "non-air-suckers" are unable to aspirate air, probably because they have not learned to relax voluntarily the superior esophageal sphincter. However, 3 such subjects were studied according to the previous procedure except that this time the spirometer was filled with air and instead of being directed to suck air they were told to make inspiratory efforts against a closed glottis. The negative pressure thus developed in the stomach withdrew air through the Levine tube from the spirometer bell. A one way flutter valve inserted in the recording apparatus, as shown in figure 5, prevented the air taken into the stomach from returning to the spirometer, and as the aspirated air accumulated in the stomach the subject eructated. Volumes of air aspirated in this manner are given in table 6, they averaged 69.2 cc. per effort.

TABLE 5—Volume of Air Aspirated into Stomach by Air Sucking

Subject	Number of Sucking Efforts	Volume Cc	Cc per Effort
1	95	1,245.2	13.0
	7	1,000.0	142.9
	10	1,745.7	174.2
	16	2,072.8	129.5
4	12	1,871	155.8
	Average	1,572.1	112.7

TABLE 6—Volume of Air Aspirated into Stomach by Inspiration against a Closed Glottis

Subject	Number of Efforts at Inspiration	Volume Cc	Cc per Effort
1	5	151.4	30.3
	12	174.2	14.5
	8	171.2	21.4
Average	~7	162.4	69.2

It is apparent that the negative intraesophageal pressures created during the inspiratory phase of respiration were sufficient to aspirate air into the esophagus when the superior esophageal sphincter was intubated. Minute volumes being calculated, the average results amounted to 39.5, 43.7 and 91.9 cc of air per minute during normal, moderate and deep respiration respectively. Thus, in one minute of very deep

LEVINE TUBE IN LOWER OESOPHAGUS

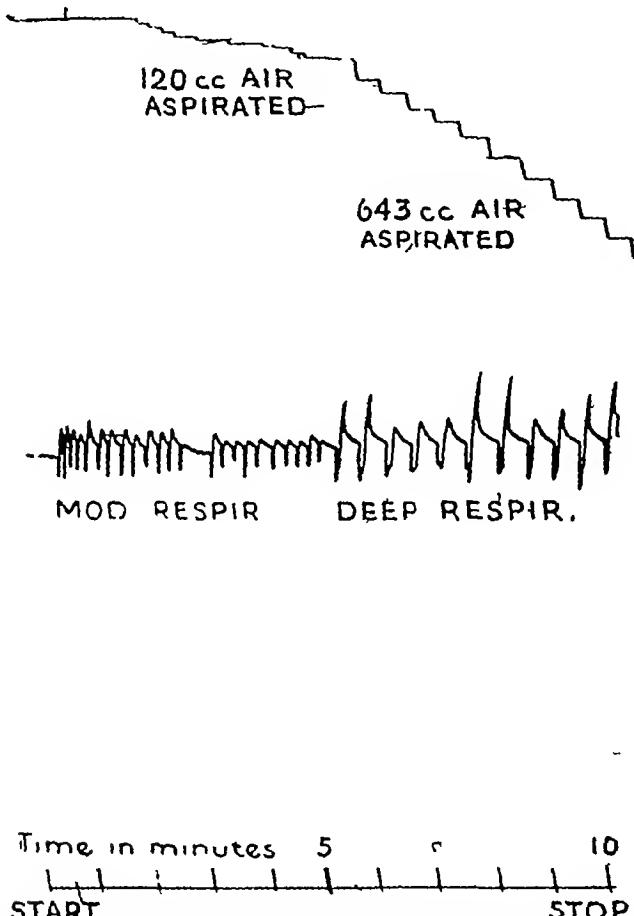


Fig 7.—Record of air "aspirated" into the esophagus during five minutes of moderate and five minutes of deep respiration. Levine tube in lower part of esophagus

respiration 232 times as much air was aspirated as during the same period of normal respiration.

C Clinical Case Studies.—1 A Case of Air Sucking Mrs N. A., a 38 year old housewife, presented a chief complaint of "attacks of belching" precipitated by "nervous excitement." In sequence her symptoms were excitement, dyspnea, abdominal distention and substernal or epigastric pain followed by rapid eructations of nonoffensive gas. These eructations had occurred twenty to thirty times

per minute, and during "attacks" they would continue from a few minutes to a whole day. Following the first attack, in 1938, the patient was hospitalized as a bed patient for six weeks because of the substernal pain which was attributed to coronary occlusion. Electrocardiographic studies failed to substantiate the diagnosis, and on return of symptoms the diagnosis was that she was "astrophasic" though swallowing was denied.

TABLE 7.—Volume (Cc) of Air "Aspirated" into Esophagus During Five Minute Periods of Respiration

	Subject Number					Average Volume Cc
	1	2	3	4	5	
Normal respiration	20.1					20.1
Moderate respiration	277.5	122.6	170.2	194.2	211.8	227.5
Deep respiration	241.2	141.7	643.1	225.5	62.0	219.0

This patient was observed fluoroscopically while she drank a half glass of thin barium meal. The lumen of the esophagus appeared moderately widened but otherwise normal and initially only a small bubble of gas was visible in the stomach, as shown in figure 8A. The patient, somewhat apprehensive, was then told that she was about to receive a rather painful treatment. This precipitated an "attack," and air immediately began to traverse the esophagus and enter the

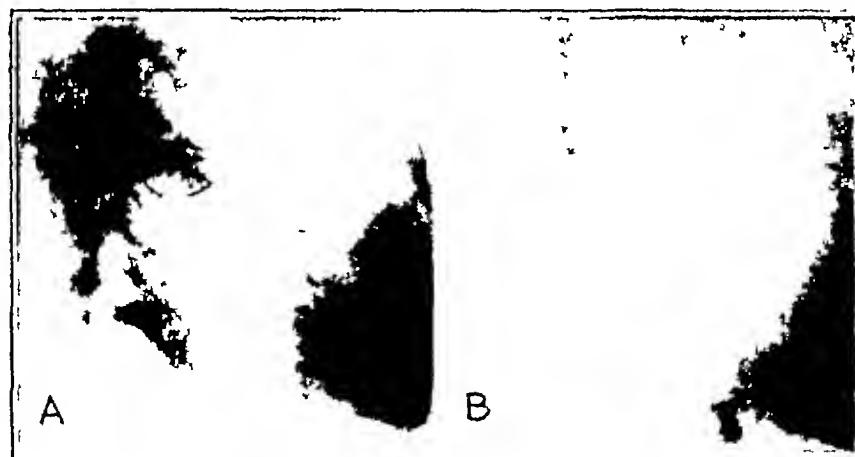


Fig. 8.—A, small gas bubble in stomach before air sucking. B, great distention of fundus of the stomach in the same patient after three seconds of air sucking.

open and snoring loudly He exhibited Cheyne-Stokes respiration, and pronounced abdominal distention had developed, though some flatus had been passed per rectum

A Wangensteen continuous gastric suction was started, and a volumetric bottle was inserted in the system to measure the gas withdrawn. During the subsequent four hours 1,000 cc. of gas was aspirated from the stomach, without any apparent effect on the degree of distention No true swallowing was noted during the time that could account for entry of the volume of gas withdrawn However, it was observed that at irregular intervals the patient's tongue seemed to fall back in the throat, obstructing respiration At the same time respiratory efforts continued, the thorax "jerking" rhythmically on inspiration Almost simultaneously with these efforts from 10 to 30 cc of gas returned through the Wangensteen apparatus

This patient seemed to be using the mechanism of air sucking With his jaw and throat relaxed he was making inspiratory efforts against a laryngeal obstruction His distention could be explained on the basis of an "aspiration" of a greater volume of air than could be readily absorbed or expelled

COMMENT AND SUMMARY

Enormous abdominal distention occasionally occurs so rapidly that exogenous air is the only feasible source of the distending gas The means, however, whereby air gains access to the upper part of the alimentary tract in such acute distention has not been definitely established, though air swallowing is generally assumed to be the mechanism involved While in the vast majority of cases no definite observations on air swallowing are reported in the literature, in several instances extensive acute distention has been observed to occur in the absence of true swallowing In an attempt to learn how this occurs conditions in which air is thought to gain entrance to the upper part of the alimentary tract without apparent swallowing have been reviewed Of significance among these are acute dilatation of the stomach, air sucking and esophageal speech

For experimental purposes acute dilatation of the stomach was selected as a representative entity amenable to study Available information indicated that in this disease large or tremendous volumes of gas not infrequently have accumulated in the stomach within a few minutes When accurate observations have been recorded swallowing was not noted to be the means of air entry, in fact, in a few cases a definite statement to the effect that swallowing did not occur has been made A review of the etiologic precursors and proposed hypotheses of the mechanism in this disease provided no adequate explanation for its occurrence, but the acute onset and the wide variety of etiologic factors strongly suggested a reflex nervous mechanism In the light of present day knowledge of extrinsic gastric innervation either reflex vagal inhibition or splanchnic stimulation could conceivably be implicated Though seldom considered of significance the possible role of abnormal respiration as a factor in the distention mechanism deserves consideration,

intubated with a Levine tube also "aspirated" significant volumes of air by inspiration against a closed glottis. In fact, merely forceful respiration caused air to enter the esophagus and accumulate in the stomach when the superior esophageal sphincter was intubated and a one way valve prevented escape of this air on expiration. In view of these findings it seems reasonable to suggest that without swallowing some reflexly induced valvelike action of the superior esophageal sphincter might conceivably account for the means of entry of air in acute distention.

Although no unequivocal solution to the mechanism of acute distention has been reached by these studies, it appears likely that in cases in which actual swallowing is not observed air sucking may be the mechanism involved. What keeps every one from sucking air is the resistance offered by the superior esophageal sphincter, and one might postulate that general debilitation, anesthesia or some reflex may decrease the tone of this structure and allow significant volumes of air to enter the upper part of the gastrointestinal tract. The possible role of respiration in such a mechanism has also been mentioned.

CONCLUSIONS

1 Considerable evidence in the literature has established the fact that atmospheric air usually constitutes the largest percentage of distending gas in acute intestinal obstruction.

2 To determine how air gains entrance to the gastrointestinal tract through the esophagus there is need for more accurate observations on patients with acute abdominal distention, with evaluation in particular of the commonly accepted role of air swallowing.

3 Comparatively large negative intragastric as well as intraesophageal pressures develop during inspiration against a closed glottis.

4 Normally the superior esophageal sphincter prevents air from entering the upper alimentary tract without swallowing.

5 By voluntarily relaxing the tone of this sphincter and inspiring against a closed glottis air suckers and patients learning esophageal speech can "aspirate" air into the esophagus and stomach.

6 The volume of air that can be "aspirated" by air suckers, and by "non-air-suckers" whose superior esophageal sphincter is intubated, is considerable.

7 In disease, during anesthesia or as a result of a reflex, a decrease in tone of the superior esophageal sphincter might readily allow the entrance of exogenous air into the upper gastrointestinal tract without swallowing. Increased negative intraesophageal and intragastric pressures developed during abnormal respiration might well be an added factor in such a mechanism.

(Dr A. C. Ivy) University of Illinois, Chicago

the small intestine of dogs, it was subsequently prepared in purer form by Gray, Bradley and Ivy⁴ from the mucosa of small intestine of hogs

METHOD

The routine Mann-Williamson operation, as reported in a separate publication,⁵ was performed on all animals. Intravenous pentobarbital sodium anesthesia was used. Silk suture material and open type anastomosis were routinely employed. Enterogastrone tablets, 0.5 mg., obtained through the courtesy of the Abbott Laboratories, were given orally, 8 tablets (4 Gm.) daily, starting one or two days postoperatively and continuing until the date of death of the animal. Diet consisted of hospital left-over food, principally meats, without vitamin or other supplements. A previously reported control series of 28 dogs on which the Mann-Williamson operation has been done⁶ was used as a basis for comparison with the present study.

TABLE 1.—Enterogastrone Series Incidence of Ulcer and Survival Time

	Dogs	Died	Ulcers	No Ulcers	Average Days After Operation	Dogs Still Alive After Operation
Control	28	28	28	0	71	0
Mann Williamson operation, enterogastrone	16	14	11	8	96 plus	1*

* Alive 259 days on April 20, 1947. See footnote at bottom of table 3.

RESULTS

Fifteen dogs, including both sexes, comprised the enterogastrone series. Fourteen dogs have died with average survival time of 84.4 days. Including the 1 living dog the average survival time is 96 days at the time of the report, compared with 71 days for the control series (table 1).

In the enterogastrone-treated series the longest survival time is 259 days (compared with 135 days in the control group), the shortest survival time was 25 days (compared with 13 days for the control group).

Eleven of the enterogastrone-treated dogs died with jejunal ulcers, (with an average survival time of 97 days). The ulcers were located

4 Gray, J. S., Bradley, W. B., and Ivy, A. C. On Preparation and Biological Assay of Enterogastrone, Am. J. Physiol. 118: 463 (March) 1937.

5 Saltzstein, H. C., Sandweiss, D. J., Hammer, I. M., Hill, E. J., and Vandenberg, H., Jr. Effect Vagotomy on Mann-Williamson Ulcer in Dogs, Arch. Surg., this issue, p. 130.

6 Beaver, D. C., Sandweiss, D. J., Saltzstein, H. C., Farbman, A. A., and Sanders, A. W. Effect of Urine Extracts on Prevention and Healing of Experimental Ulcers in Dogs, Am. J. Clin. Path. 12: 617 (Dec.) 1942.

in the jejunum opposite the gastroenterostomy stoma, in the direct line of flow of gastric contents Grossly, the ulcers varied in diameter from 0.5 cm to 6.0 cm One animal showed three ulcers In the remainder, only one ulcer was present Jejunitis was not observed in any of the dogs Ulcers of 4 of the animals were examined microscopically They failed to show epithelialization, but in all there was a varying degree of fibroblastic and vascular proliferation of the ulcer base which did not vary significantly from that observed in the control series

Of the 11 dogs with jejunal ulcer, 10 had perforated ulcers, generalized peritonitis accounting for death The ulcer in the eleventh animal was superficial, the animal dying from pneumonia Three dogs died without ulcer (with an average survival time of 38 days) The cause of death in those animals is shown in table 2

The 1 living dog in the enterogastrone series (259 days of post-operative survival) went through a successful pregnancy during treatment, which might have had some beneficial effect (on its survival time)

TABLE 2.—*Enterogastrone Series Survival and Causes of Death in Dogs Without Ulcer*

Dog	Days After Operation	Cause of Death
1	60	Cachexia
2	30	Peritonitis
8	25	Intestinal obstruction, intussusception

for peptic ulcer in women has been shown to be relieved and benefited during gestation⁷ (Also see footnote at bottom of table 3)

COMMENT

In the present series some benefit from the oral administration of enterogastrone was observed Three (21 per cent) of 14 dogs did not experience ulcer as compared with the presence of ulcer at autopsy in all of the 28 dogs in the control series

Three of the animals that died with ulcer lived longer than the maximum survival time of our control animals (i e, 186, 180 and 256 days) One of the enterogastrone-treated animals is still alive and in good condition two hundred and fifty-nine days after the Mann-Williamson operation (See footnote at bottom of table 3)

The incidence of ulcers (79 per cent) and average survival time of 96 days in the present series compare unfavorably with results of a

7 Sandweiss, D J , Saltzstein, H C , and Farbman, A A Prevention or Healing of Experimental Peptic Ulcer in Mann-Williamson Dogs with Anterior Pituitary-Like Hormone (Antuitrin S) Preliminary Report, Am J Digest Dis 5 24 (March) 1938

similar series reported by Ivy.⁶ The fact that the diet in our series was not supplemented by pancreas or raw liver may have contributed to the comparatively short survival time. However, our control series did not receive these supplements in their diet. It is also possible that the enterogastrone used by Ivy, and prepared in his own laboratory, might have been more potent. However, the commercial product fed our dogs was prepared by the same method and under Dr. Ivy's direction. If the difference in our results should be explained by variation in potency, then indeed, the present method of preparing enterogastrone and the present method of assaying the potency of the product need immediate reevaluation if it is to be used therapeutically on patients with ulcers.

TABLE 3.—Enterogastrone Series Summary of Results

Dog	Survival Time, Days	Ulcer		Cause of Death
		Appearance	Measurements	
1 (dog 2, table 2)	30	None		
2	89	Perforated	8 mm diameter	Peritonitis
3	88	Perforated	8 x 5 cm.	Peritonitis
4	56	Superficial	1 cm	Pneumonia
5 (dog 1, table 2)	60	None		Cachexia
6	52	Perforated	1 x 1 cm	Peritonitis
7	176	Perforated	5 x 3 cm	Peritonitis
8	88	Perforated	8 ulcers 0.5 x 0.5 cm	Peritonitis
9	73	Perforated	1 x 1 cm	Peritonitis
10 (dog 3, table 2)	25	None		Intussusception
11	80	Perforated	1 cm diameter	Peritonitis
12	35	Perforated	1 x 1.5 cm	Peritonitis
13	256	Perforated	1.5 x 1.5 cm	Peritonitis
14	180	Perforated	2 cm diameter	Peritonitis
15	250* (4/20/47)	Still alive		
Average (exclusive of dog 15)	84.4	No ulcer	8	
Average (inclusive of dog 15)	96	Perforated 10 Superficial 1 Still alive 1		

* An exploratory operation was performed 280 days after operation. The upper gastro-enterostomy stoma was clean and smooth and there was no ulcer or induration. However, the lower anastomosis was found to have been made 22 inches (55.8 cm.) from the ileocecal valve instead of the routine 10 to 12 inches (25 to 30 cm.), and this might have been responsible, at least in part, for the prolonged postoperative survival time and the absence of an ulcer at the time of the exploratory operation.

SUMMARY

The effect of orally administered enterogastrone in a series of 15 dogs on which the Mann-Williamson operation had been done was studied. Results were compared with a previously conducted control series of 28 dogs.

Survival time of the enterogastrone-treated series is 96 days while that of the control series was 71 days.

Twenty-one per cent (3 dogs) of the enterogastrone-treated series did not have ulcer, there was an average survival time of 38 days for this

group. Of the 79 per cent (11 dogs) that died with ulcer (average survival time 97 days) 10 had perforated ulcers. In the control series, all the dogs showed ulcer at autopsy, and 72 per cent of the ulcers were perforated.

Three of the enterogastrone-treated animals that died with ulcers lived longer than the maximum survival time of our control dogs 175, 180 and 256 days. One of the treated dogs is still alive and in good condition 259 days after the Mann-Williamson operation. (See footnote under table 3.)

The results of this study show that some beneficial therapeutic effect on experimental Mann-Williamson ulcers in dogs was obtained by the oral administration of enterogastrone.

EFFECT OF VAGOTOMY ON MANN-WILLIAMSON ULCERS IN DOGS

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DETROIT

THE PRESENT study was conducted for the purpose of determining the effect of vagotomy on experimentally produced Mann-Williamson peptic ulcers in dogs. Although there are other methods of experimentally producing peptic ulcers, the Mann-Williamson operation was chosen because the jejunal ulcer which ensues closely simulates the postoperative jejunal ulcer seen in man. In 98 to 100 per cent of control animals jejunal ulcers develop after the operation.

METHOD OF STUDY

The Mann-Williamson operation was performed in the standard manner, viz transection at the pylorus, closure of the duodenal stump, transection of the jejunum 4 inches (10.1 cm) beyond Trietz' ligament, end to side gastrojejunostomy using the distal cut portion of the jejunum and side to side jejunoleostomy anastomosing the proximal cut portion of the jejunum to the ileum 25 cm above the ileocecal valve (fig 1). This short-circuits the bile, pancreatic juice and duodenal secretions into the terminal ileum. Ulcers nearly always form directly opposite the gastroenterostomy stoma. The short-circuiting of the upper segment of the small bowel causes nutritional disturbance resulting in loss of weight and frequently in diarrhea. Ivy¹ has obviated this by daily feedings of whole pancreas and liver. In the present study the diet consisted of hospital left-over food, principally meats, with no supplements, similar to the diet given to our control series.

Intravenously administered pentobarbital anesthesia was used, the average dose being 1 grain (0.06 Gm) per 5 pounds (2.3 Kg) of body weight. Endotracheal intubation was used in all cases. Surgical approach for vagotomy was made through the left seventh interspace. The trunks of the two main vagus nerves and any anastomosing branches were isolated in the immediate supradiaphragmatic region and a 1 to 2 inch (2.5 to 5 cm) segment of the anterior and posterior vagi, with all visible branches, was removed. Oxygen was administered as necessary. The lungs were reexpanded before the chest wall was closed. In several cases the chest was aspirated postoperatively to determine the presence or absence of

From the Research Division, Harper Hospital

Presented at the fourth annual meeting of the Central Surgical Association,
Chicago Feb 22 1947

1 Ivy, A C The Problem of Peptic Ulcer, J A M A 132 1053-1059
(Dec 28) 1946

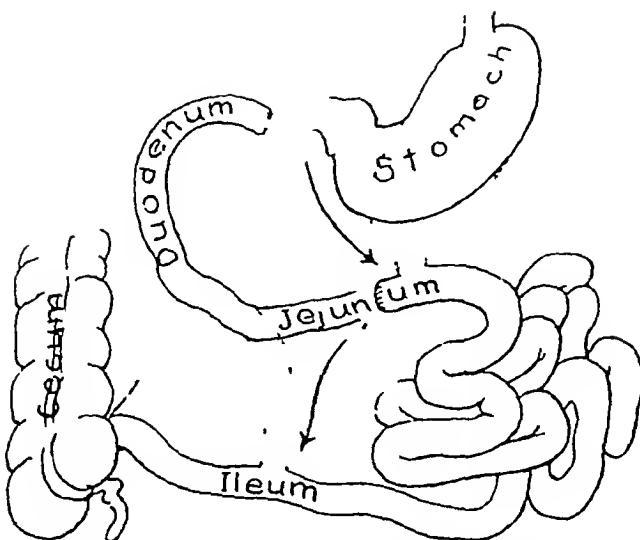


Fig 1.—The Mann-Williamson operation. The diagram shows steps in the procedure (1) transection of stomach at pylorus and closure of duodenal end, (2) end to side gastrojejunostomy utilizing upper part of jejunum, and (3) jejunointerostomy at 25 cm above cecum



Fig 2 (dog 4)—Jejunitis of mild severity. Animal survived thirty-three days after vagotomy. The mucosa shows patchy reddening with some confluence. No ulcer is present

pneumothorax and therapeutic aspirations were repeated daily as necessary. Usually one or two aspirations sufficed.

Vagotomy preceded the Mann-Williamson operation in 1 animal (table 1, dog 1). The postvagotomy gastric dilatation so frequently encountered made the Mann-Williamson operation more difficult to perform. Performing of the two procedures simultaneously was tried, but the animals withstood these operations poorly and only 1 survived long enough to be included in the series (table 1, dog 10). Vagotomy was performed after the Mann-Williamson procedure in 10 cases.

The average interval between the Mann-Williamson operation and vagotomy was eleven days. In compiling our results no animal was used unless it survived the second operation for a minimum of twelve days.

Preoperative care consisted of twenty-four hour fasting. No preoperative medication was given. Routine postoperative care following the Mann-Williamson



Fig 3.—Severe jejunitis. The animal survived five days after vagotomy (therefore not included in the series). Note diffuse, marked reddening and thickening of mucosa, present in upper 25 cm of jejunum.

operation consisted of administration of fluids orally for twenty-four hours, followed by a general diet. Five per cent dextrose in saline solution was occasionally given postoperatively, intravenously or subcutaneously during the first few post-operative days, when indicated. Following reaction from anesthesia after vagotomy the regular diet was resumed. Gastric aspiration was performed on 5 dogs (dogs 6 through 10, table 1). Aspiration was performed once daily for four days routinely and then discontinued unless the stomach contained abnormal amounts of food or fluid.

RESULTS

CONTROL MANN-WILLIAMSON ULCER SERIES

A previously reported series of 28 control dogs with Mann-Williamson ulcers has been used for comparison.² All of these ani-

mals died with typical jejunal ulcers, the average survival time was seventy-one days following operation (minimum thirteen days and maximum one hundred and thirty-five days) Seventy-two per cent of the animals died of peritonitis following perforation of an ulcer Only two of the ulcers showed attempts at healing There was no evidence of jejunitis or gastric dilatation in any of the cases

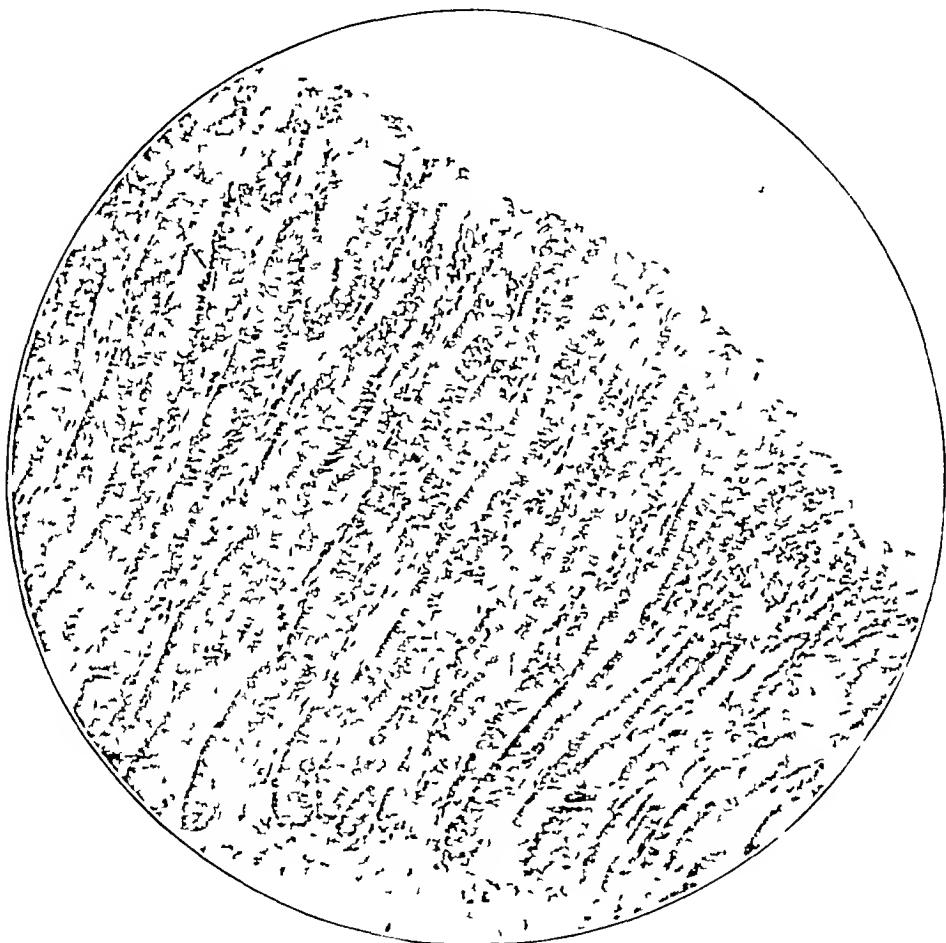


Fig 4.—Normal jejunum of dog showing mucosa Note regular arrangement and length of villi $\times 125$

MANN-WILLIAMSON-VAGOTOMY SERIES

In this series 12 dogs survived the Mann-Williamson operation nineteen days or longer, and the vagotomy operation twelve days or longer These 12 dogs comprise our series

2 Beaver, D C., Sandweiss, D J., Saltzstein H C., Farbman A A and Sanders, A W Effect of Urine Extracts on Prevention and Healing of Experimental Ulcers in Dogs Am J Clin Path 12: 617-629 (Dec) 1942

1 Postoperative Survival Time.—The survival time was considerably shorter in the vagotomized series than in the control series, being fifty-one days following the Mann-Williamson operation (forty-four days following vagotomy) compared to seventy-one days for the control series.

2 Mann-Williamson Ulcers.—Jejunal ulcers were found in 6 of the 12 animals (table 1). Of greater significance, however, is the fact

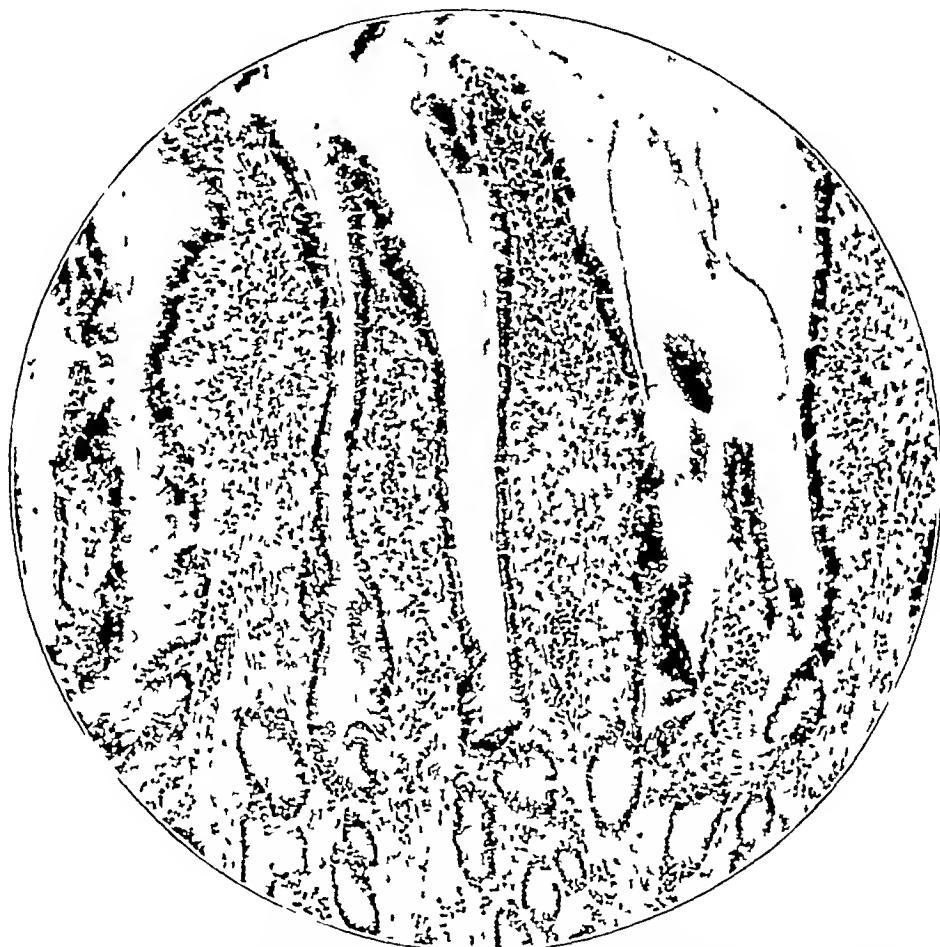


Fig 5.—Severe jejunitis in dog after vagotomy and Mann-Williamson operation. Note thickening and increased length of villi with cellular infiltration. Under same magnification as figure 4, $\times 125$.

that of the 8 animals that lived more than one month after the Mann-Williamson operation (twenty-four days after vagotomy) 6 were found to have ulcers.

In previous experience, if any substance or method had a prophylactic or therapeutic effect on Mann-Williamson ulcers, it was more evident the longer the dog survived, i.e., some of the ulcers which

routinely develop after one or two months were prevented or healed, or the survival time of the animal was prolonged. These beneficial effects were not observed after vagotomy.

Of the 6 animals that died with ulcer, in 2, a single small superficial ulcer was present. Two others had penetrating ulcers (one 0.5 cm in diameter, the other 3.0 cm in diameter). One had three ulcers (each measuring 1 cm in diameter, one perforated, one penetrating and one superficial). The last dog had an ulcer which was 2 cm in diameter and had perforated.

TABLE 1.—*Series of Dogs on Which the Operation and Vagotomy Were Performed*

Dog	Operation, Days	Mann William- son Days	Sur- vival Vagot- omy, Days	Dilatation 0 to —	Ulcer		Jejunitis 0 to —
					Type	Diameter	
1*	1.7	152	—	—	Penetrating	3.0 cm	—
2	59	43	—	—	Superficial	0.5 cm	0
3	34	24	—	0	Perforated	3.5 cm	—
4	38	33	—	—	None	—	—
5	60	28	—	—	Superficial	1.0 cm	—
6	60	38	—	0	Penetrating	0.5 cm	0
7	61	74	—	0	None	—	0
8	10	12	—	—	None	—	—
9	25	17	—	—	None	—	—
10†	47	47	—	—	Perforated	1.0 cm	0
					Penetrating	1.0 cm	0
					Superficial	1.0 cm	0
11	10	14	—	—	None	—	—
12	21	16	—	—	None	—	0
Average Totals	51	44		Dilatation —9 None 3	Ulcer—6 No ulcer—6		Jejunitis—7 None—5

* Vagotomy performed twenty-five days before Mann Williamson operation. Vagotomy did not prevent ulcer formation.

† Mann Williamson operation and vagotomy performed simultaneously. Vagotomy did not prevent formation of ulcer.

Note.—Four of the 6 dogs that died without ulcer lived on the average only twenty-one days after the Mann Williamson operation. It is possible that had these animals lived longer, typical ulcers might have developed as occurred in 6 of the remaining 8 animals with an average post operative (Mann Williamson) survival time of sixty-five days.

The ulcers of 4 of the animals were examined microscopically. Epithelialization of the surfaces of the ulcer was not observed. The surfaces were necrotic with varying numbers of cells of acute and chronic inflammation. Fibroblastic and vascular proliferation of the base was present in all cases in considerable degree but the appearance did not differ appreciably from that found in the previously reported control series.²

It is of interest to note that in 1931 Beaver and Mann³ reported results on 3 control dogs with Mann-Williamson ulcers, 3 dogs with Mann-Williamson ulcers with splanchnic nerve resection and 3 dogs with Mann-Williamson ulcers and supradiaphragmatic vagotomies. In all the typical jejunal ulcers developed with the exception of 1 in the latter

³ Beaver, M. G. and Mann, F. C. The Production of Peptic Ulcer After Section of the Gastric Nerve. Ann. Surg. 94: 1116-1119 (Dec.) 1931.

group. They concluded that "Section of nerves to the stomach did not prevent the development of ulcer in that portion of the intestines which received the gastric content after measures had been taken to drain the duodenal secretion away from that region."

3 Jejunitis in the Vagotomized Animals.—In 7 of the 12 dogs jejunitis of varying severity was present. It was located in the upper

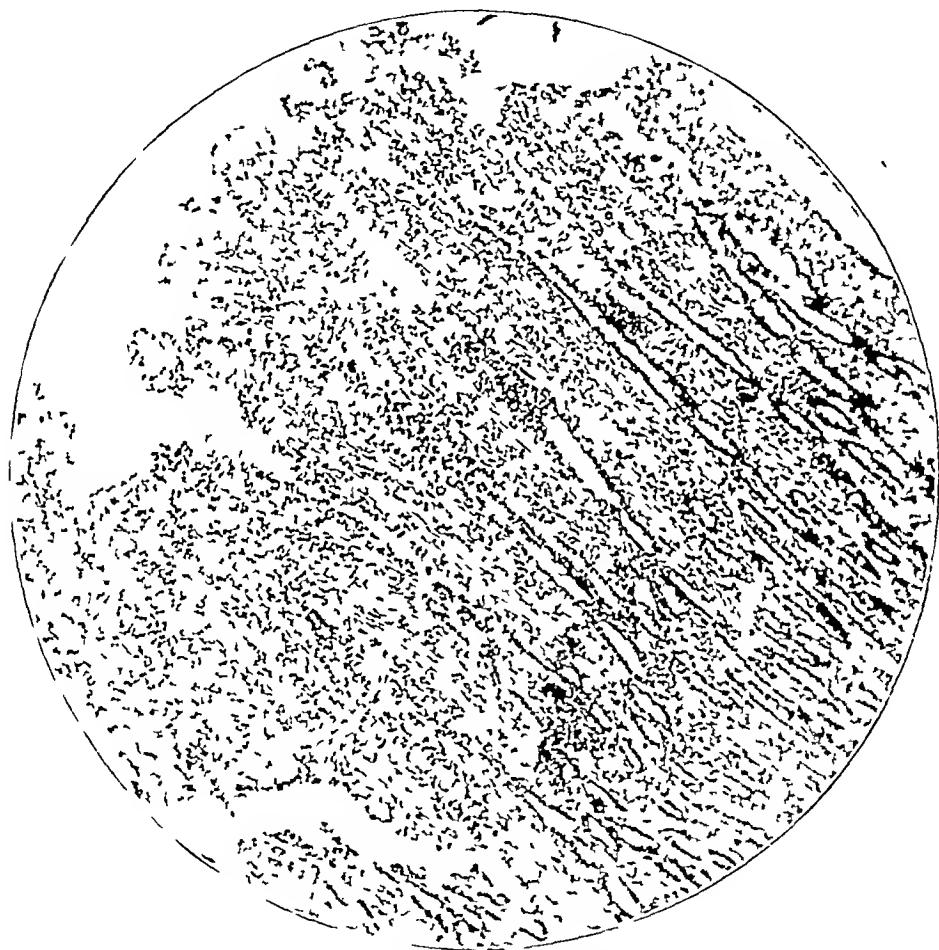


Fig 6.—Jejunitis in dog after vagotomy and Mann-Williamson operation. Note edema, hyperemia and cellular infiltration of terminal villi. More normal villi near base. $\times 125$

part of the jejunum, usually confined to the upper 14 inches (35.5 cm.) or less. The most extensive area of involvement was 18 inches (45.7 cm.). Its minimal manifestation was a patchy mucosal reddening, for several inches beyond the anastomosis (see fig 2). Its maximum manifestation was a diffuse reddening and carpet-like thickening

and hypertrophy of the mucosa, most severe in the upper portion, beginning immediately at the gastrojejunostomy anastomosis and gradually tapering off distally (see fig 3) Analysis of the 7 cases reveals that in 2 cases the jejunitis was diffuse and severe for 18 inches and 14 inches respectively In 4 cases it was of moderate severity In 1 case it was scattered and mild, the intensity of redness being less marked than in the other observed cases No correlation with

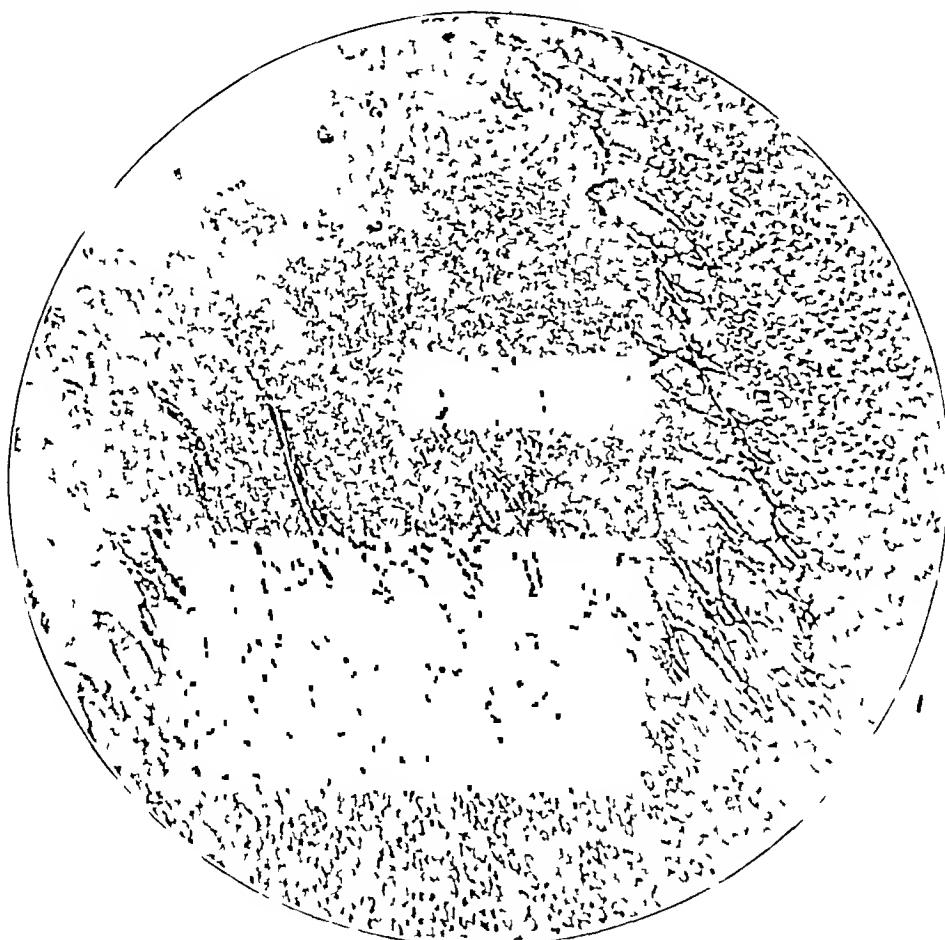


Fig 7.—Jejunitis in dog after vagotomy and Mann-Williamson operation. The mucosa is about twice the normal thickness with terminal villi as described in figure 6. $\times 75$

survival time was observed The 2 severe cases were present in dogs with survivals of one hundred and eighty-two and twenty-four days after vagotomy The cases of moderate jejunitis occurred in dogs with survivals of thirty-three, seventeen, fourteen and twelve days, the average time of survival being nineteen days The mild case was in 1 dog that survived twenty-eight days

Microscopically, there were marked hypertrophy and edema of the villi, engorgement and proliferation of capillaries and especially in the free ends of the villi. There were subacute inflammation with infiltration of round cells and a smaller number of polymorphonuclear leukocytes (figs. 4, 5, 6 and 7).

Of the 6 dogs with jejunal ulcers severe jejunitis was present in 2, and it is worthy of note that both of these cases represented dogs with the largest ulcers in the series, one a 3.5 cm diameter ulcer which perforated causing death on the twenty-fourth postoperative day and the other a 3 cm ulcer which had penetrated deeply. The latter animal survived one hundred and eighty-two days, the only one in which vagotomy was done before the Mann-Williamson operation.

Of the 5 remaining cases of jejunitis no ulcer was present in 4 of the dogs having moderately severe jejunitis. In the case of mild jejunitis a superficial ulcer 1 cm in diameter was present.

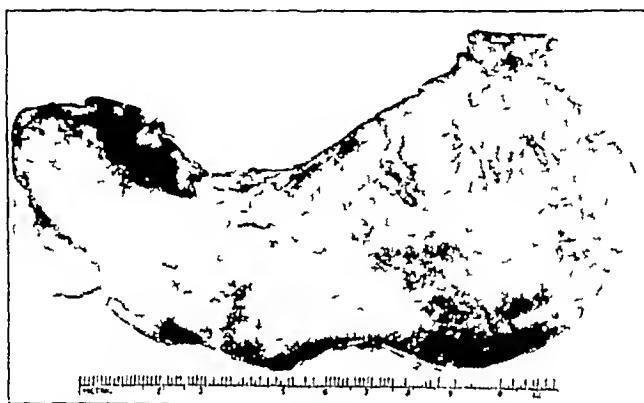


Fig. 8.—Normal stomach in dog that survived one day after Mann-Williamson operation.

As stated, 7 of our 12 vagotomized dogs that had Mann-Williamson ulcers were found to have jejunitis of varying severity. Based on our experience with over 350 dogs with Mann-Williamson ulcers used as controls and treated with various medicaments, the finding in our laboratory of jejunitis in 60 per cent of our vagotomized dogs that had Mann-Williamson ulcers is definitely significant.

4. *Gastric Dilatation*.—Gastric dilatation was present at autopsy in 9 of the 12 dogs (75 per cent) (figs. 8 and 9). It was usually a sacular dilatation, involving only the fundus and body of the stomach, with the antrum contracted and tubelike. Table 2 shows the degree of dilatation and the correlation with postoperative survival time.

Table 2 shows that gastric dilatation was most frequently found in animals surviving for the shortest time, in that 5 of the 9 cases were

in animals that survived less than one month. However, 1 dog showed marked dilatation one hundred and eighty-two days after vagotomy.

TABLE 2—*Gastric Dilatation*

Degree of Dilatation	Number of Dogs	After Vagotomy, Survival Time		
		0-30 Days	30-60 Days	Over 60 Days
Marked	3*	1	1	1
Moderate	3	1	2	
Mild	3	3		
Totals	9	5 (Av 17 days)	3 (Av 41 days)	1 (182 days)

* Cause of death in 2 cases.

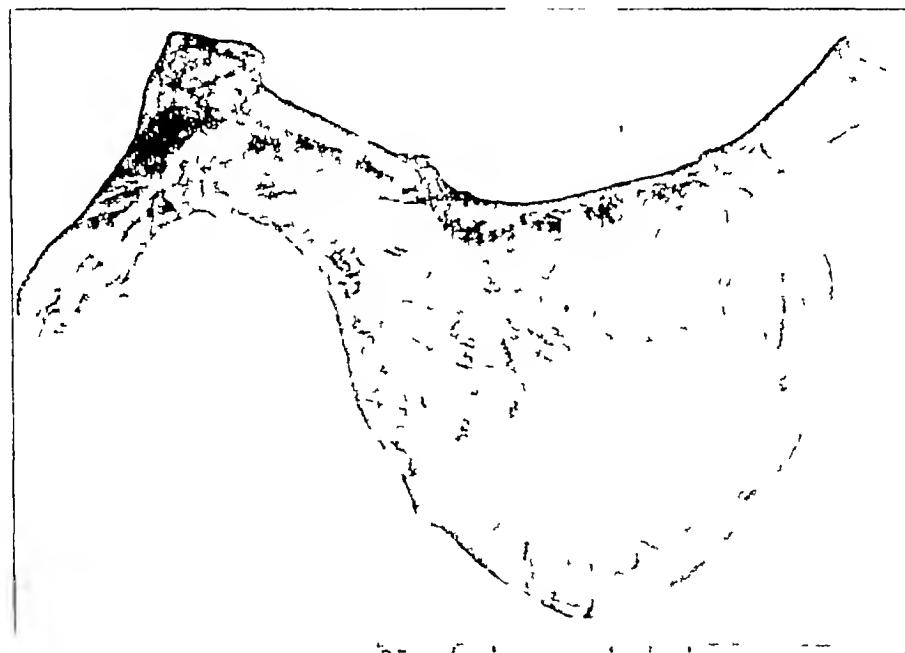


Fig. 9.—Gastric dilatation of type frequently seen after Mann-Williamson operation and vagotomy. Note pouchlike dilatation of fundus and contraction of antrum.

SUMMARY

Twenty-eight control dogs survived the Mann-Williamson operation an average of seventy-one days. Twelve dogs on which vagotomy plus the Mann-Williamson operation was performed survived a much shorter time, i.e., fifty-one days after the Mann-Williamson operation and forty-four days after vagotomy. Of the controls 100 per cent showed ulcer at autopsy, 72 per cent of these died of peritonitis with peritonitis. Of the vagotomized animals in 6 of the 8 that lived more than one month after the Mann-Williamson operation jejunal ulcers developed.

An inflammatory reaction of varying severity was found in the upper part of the jejunum in 7 of 12 dogs on which Mann-Williamson operations and vagotomy were performed. There was no correlation with survival time. Gastric dilatation was present in 9 of the 12 dogs. This occurred more frequently in dogs with short survival time, but 1 animal showed marked gastric dilatation one hundred and eighty-two days after vagotomy. (The vagotomy was done twenty-five days before the Mann-Williamson operation.)

CONCLUSIONS

The postoperative survival time of dogs on which the Mann-Williamson operation and also transthoracic vagotomy were performed was much shorter than that of the control animals. In 6 of 8 dogs on which both operations were done and which lived one month ulcer developed. Gastric dilatation was present in 75 per cent of the vagotomized dogs, most frequently in those of short survival. Jejunitis of varying severity was present in 60 per cent of the vagotomized dogs.

If such jejunitis should be found to exist in patients after vagotomy, it might explain the diarrhea which at times follows this surgical procedure.

SECTION OF THE VAGUS NERVES TO THE STOMACH IN THE TREATMENT OF BENIGN GASTRIC ULCER

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DURING the past four years, section of the vagus nerves to the stomach as a method of treatment has been carried out at the University of Chicago in 250 patients with various types of peptic ulcer. The technics employed have been described elsewhere.¹ The clinical results following this method of treatment have been so satisfactory that it has replaced all other types of surgical treatment for this disease on our service. One patient in this series died of pneumonia, making a mortality of 0.4 per cent. Physiologic tests on 170 patients on whom the operation was performed by us have revealed that the section of the vagus nerves was probably incomplete in 18 cases. In this group, 6 patients have complained of recurrent or persistent symptoms of ulcer, and in 2 of these an undamaged vagus fiber was found at a second operation. Division of this nerve was followed by complete relief. The remaining 164 patients have remained free from all types of ulcer distress on an entirely unrestricted diet and without medication. The side effects of section of the vagus nerves, such as symptoms of delayed gastric emptying and diarrhea, which have been discussed elsewhere, have proved to be transitory and, on the whole, inconsequential. The operation was performed by the transthoracic approach in 61 patients and by the transabdominal route in 109 patients. It was combined with gastroenterostomy in 71 patients, and in 5 patients with cicatricial obstruction at the pylorus a subsequent gastroenterostomy was required. The operation was performed in 147 patients for duodenal ulcer, in 15 patients with gastrojejunal ulcer and in 8 patients with gastric ulcer. The present paper is concerned with the latter group.

From the Department of Surgery of the University of Chicago

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¹ Dragstedt, L. R. and Shaffer, P. W. Removal of the Vagus Innervation of the Stomach in Gastroduodenal Ulcer. *Surgery* 17:742-749 (May) 1945.

While there is no reason to believe that the pathogenesis of gastric ulcer is in any way different from that of ulcer of the stomach or jejunum, the possibility of cancer in the former case makes it an entirely different and special surgical problem. When the lesion is in the pyloric antrum and readily accessible, it is probably best treated by a subtotal gastrectomy. This operation can now be performed with a negligible mortality. A recurrent gastrojejunal ulcer is rare following subtotal gastrectomy for gastric ulcer, although a definite hazard in cases of duodenal ulcer. If microscopic examination reveals that the lesion is malignant, a local removal has been accomplished and the diagnosis has been made, the advisability of further radical surgical treatment can be considered. When, however, the lesion is high on the lesser curvature close to the esophagus, a resection extensive enough to have any meaning for the treatment of a possible malignant growth would involve a total gastrectomy. This operation is much more hazardous than partial gastrectomy, and the resulting digestive and nutritive defect constitutes a definite disadvantage. When these facts are taken into consideration, together with the small percentage of gastric cancers that can be cured by any type of surgical treatment, a total gastrectomy is not justified in the absence of a definite diagnosis of malignant growth.

In the patient with a gastric ulcer and a coexistent active duodenal ulcer, the possibility of malignant growth is generally believed to be extremely small. There were 3 cases of this type in our series, all refractory to medical management. Following section of the vagus nerves to the stomach, the ulcers healed as demonstrated by fluoroscopic examination or gastroscopy. Healing took place within two weeks in 1 case, and within four weeks in the remaining 2. These ulcers have not recurred, and the patients have remained free of ulcer distress without medication or any type of dietary restriction.

REPORT OF CASES

CASE 1—A 38 year old police officer complained of intermittent attacks of typical ulcer distress for the preceding three years. Nine months before admission, he was operated on elsewhere for a perforated duodenal ulcer. On his admission, roentgen examination revealed ulcer crater in both the pyloric antrum and the duodenal bulb (fig 1A). Transthoracic section of the vagus nerves to the stomach was performed on May 3, 1947, and after this operation the patient has been free of distress without medication or dietary restriction. Roentgen examination on May 31 (fig 1B) revealed that both ulcers were healed. Nine months after the vagotomy, an episode of acute gastric distention occurred following the excessive ingestion of food. This was completely relieved by three days of gastric decompression.

CASE 2—A 42 year old male office worker complained of epigastric distress refractory to medical management for the preceding eighteen months. Roentgen

examination (fig 2A) revealed two ulcer craters on the lesser curvature of the stomach, together with deformity of the duodenal bulb with a crater. At gastroscopy, two sharply punched out gastric ulcers, 1 and 1.5 cm. in diameter respectively, were visualized. Section of the vagus nerves with posterior gastroenterostomy was performed on Nov 1, 1946. The epigastric pain was immediately relieved.

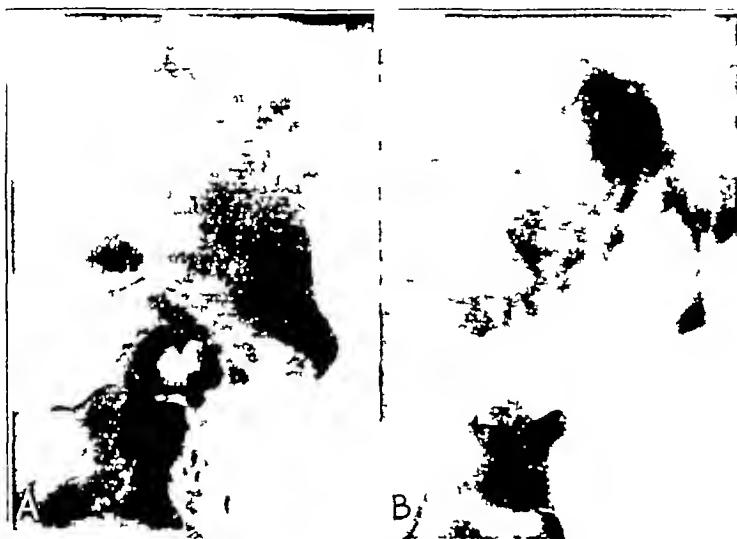


Fig 1 (case 1)—*A*, roentgenogram showing large ulcer crater in the antrum; *B*, roentgenogram twenty-eight days after gastric vagotomy showing disappearance of crater in antrum.



Fig 2 (case 2)—*A*, roentgenogram showing two ulcer craters on the lesser curvature of the stomach; *B*, roentgenogram ten days after gastric vagotomy showing almost complete healing of the ulcers shown in *A*.

The typical distress was reproduced on November 2 and 3 by the installation of a solution of hydrochloric acid into the stomach (the Palmer acid test). On November 11 roentgen examination (fig 2B) revealed complete healing of the ulcers, and gastroscopic examination the following day confirmed this. The patient has remained entirely free of symptoms to the present.

CASE 3—A 39 year old man, a streetcar conductor, complained of intermittent attacks of epigastric distress with occasional melena for the previous ten years. Roentgen examination revealed pronounced deformity of the duodenal bulb with crater and stiffness of the lesser curvature of the stomach with two small craters in this area. The gastric ulcers were visualized at gastroscopic examination. Section of the vagus nerves to the stomach with anterior gastroenterostomy was performed on Sept. 25, 1946, and at this operation, the interior of the stomach was inspected. The ulcers were readily seen and appeared benign. Gastroscopic examination on October 3 revealed that the gastric ulcers had healed, and roentgen examination on December 16 showed complete disappearance of the ulcer craters. The patient has remained free of ulcer symptoms and has a ravenous appetite.

In 3 of the patients in this series, large chronic gastric ulcers were present high on the lesser curvature of the stomach. These patients have been repeatedly examined over periods of two to four years in the medical department of this hospital with repeated fluoroscopic and gastroscopic studies. During this time, the ulcers had proved refractory to all types of medical management, including roentgen therapy to the stomach. Subtotal gastrectomy as a method of treatment had been refused. In all 3 cases, the ulcers healed promptly after section of the vagus nerves, and in 1 instance healing was apparent within a three week period as determined by roentgen examination. All these patients have remained well, 1 for over three years and 1 for over two years.

CASE 4—A 46 year old male laborer was first seen in April 1941, at which time he gave a history of burning epigastric distress relieved by food for the previous two years. Roentgen examination was reported to reveal an ulcer high on the lesser curvature of the stomach. Resection of the stomach was advised but refused. Repeated gastroscopic and fluoroscopic examinations were made. On June 25, 1943, an ulcer 1 by 2 by 15 cm. was visualized at gastroscopy. Fluoroscopic examination at this time revealed the ulcer crater shown in figure 3A. On July 7 a transthoracic section of the vagus nerves to the stomach was performed. The ulcer distress was promptly and entirely relieved, and the patient returned to his usual occupation. Gastroscopic examinations on Oct. 22 and Dec. 27, 1943, and March 27, June 5, Aug. 27, Nov. 6, 1944, and May 21, 1944, have revealed no recurrence of the previous ulcer. This has been confirmed by roentgen examination on Feb. 11, 1944 (fig 3B).

CASE 5—A 43 year old male laborer has been treated in this clinic for diabetes mellitus since 1933. In May 1941 he experienced severe abdominal pain, and a gastric ulcer with a small perforation was diagnosed. The patient recovered on medical management. Later, the ulcer symptoms returned, and in spite of a diagnosis of possible malignant growth the patient refused gastric resection.

Repeated gastroscopic and roentgen examinations were made, and during this time the patient continued to have recurrent attacks of pain with associated vomiting. On March 1, 1945 a transthoracic section of the vagus nerves to the stomach was performed. On April 17 roentgen examination revealed no evidence of a crater, and this was confirmed on May 11, 1945 and June 9, 1946. Gastro-



Fig 3 (case 4)—*A*, roentgenogram showing a large ulcer crater on the lesser curvature of the stomach. *B*, roentgenogram showing complete healing of the ulcer shown in *A*, seven months after gastric vagotomy.

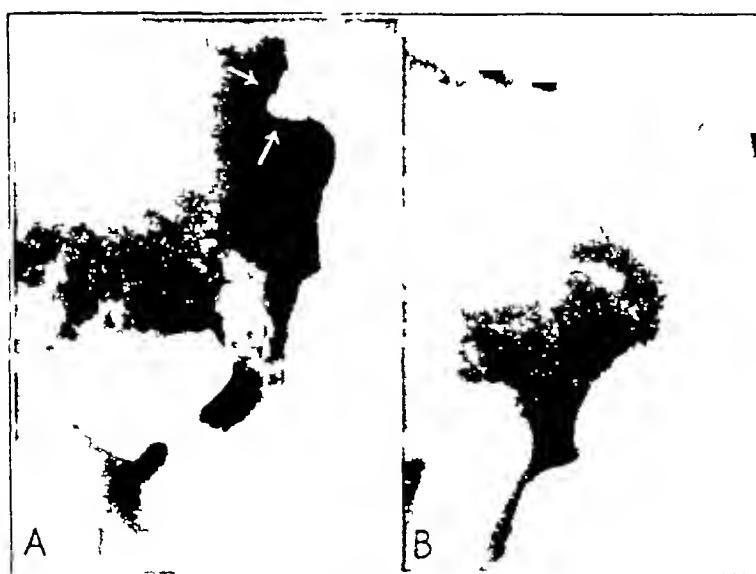


Fig 4 (case 6)—*A*, roentgenogram showing a large ulcer crater high on the lesser curvature of the stomach. *B*, roentgenogram showing healing of ulcer shown in *A*, twenty-one days after gastric vagotomy.

scopic examination on May 18, 1945 revealed what appeared to be a benign gastric ulcer, and this had disappeared on reexamination by the gastroscope on September 7. This man has remained entirely well except for occasional attacks of diarrhea.

CASE 6.—A 46 year old machinist has complained of recurring attacks of epigastric pain relieved by food and alkali since April 1942. A gastric ulcer was demonstrated by roentgen examination at that time, and he has since been followed in this clinic with repeated roentgen and gastroscopic studies. The ulcer healed and recurred three times. On Nov 12, 1946 roentgen examination revealed a large ulcer high on the lesser curvature of the stomach (fig 4A). On December 4 a subdiaphragmatic section of the vagus nerves to the stomach was performed. Roentgen examination twenty-one days later (fig 4B) revealed complete healing of the ulcer. This was confirmed by gastroscopy on Jan 28, 1947 and repeated roent-



Fig 5 (case 7).—*A*, roentgenogram showing a large ulcer crater on the lesser curvature of the stomach. *B*, roentgenogram revealing failure of ulcer in *A* to heal two months after gastric vagotomy (lesion probably malignant).

gen examination on January 26. Since this time, the patient has been entirely free from ulcer distress and has returned to his usual occupation. He complains occasionally of belching and postprandial distention of the upper part of the abdomen, which is completely relieved by "urecholine" (carbaminoyle-beta-methylcholine chloride).

The 2 remaining patients in this series also had chronic gastric ulcers high on the lesser curvature of the stomach. In 1 patient, a diagnosis of gastric ulcer was made elsewhere two years previously, but gastrectomy was refused. The second patient had been treated for three months on the medical service of this hospital, and the ulcer had proved completely refractory to treatment. In these patients, a differential diagnosis between benign gastric ulcer and carcinoma could not

be made even with the aid of laboratory studies, roentgen examination and gastroscopic observation. Palpation and inspection of the lesion at laparotomy were also not decisive. Section of the vagus nerves to the stomach was carried out in preference to a total gastrectomy. This was done as a type of therapeutic test. Although there was complete symptomatic relief in both cases, the ulcers failed to heal, as revealed by fluoroscopic examination. Total gastrectomy was, therefore, advised.

CASE 7—This 57 year old train dispatcher had been troubled by burning epigastric distress relieved by food since 1938. In 1942, and again in 1945, a gastric ulcer was reported to have been demonstrated by roentgen examination. He was first seen in this clinic on Feb 11, 1946. Roentgen examination on March 4 revealed a large ulcer on the lesser curvature of the stomach. This was confirmed by gastroscopic examination. Repeated reexamination with roentgen rays and the gastroscope during the next four months revealed no evidence of healing of the ulcer on strict medical management. Roentgen examination on August 14 showed a persistent ulcer (fig 5 A). The patient was admitted to the hospital for further study. The gastric content aspirated after the administration of histamine subcutaneously revealed a low concentration of free acid, and there was no free acid in the twelve hour night gastric aspiration. The patient had severe hypertensive cardiovascular disease and had suffered two previous cerebral accidents. Laparotomy was performed on August 15. A thickening of the gastric wall was palpable high on the lesser curvature posteriorly, and a sharply demarcated ulcer crater was felt in the center of this area. The lesion appeared grossly to be benign. It was decided, in view of the patient's cardiovascular disease and obesity and a rather unsatisfactory spinal anesthetic, that a total gastrectomy would be too hazardous and accordingly a transabdominal section of the vagus nerves to the stomach was performed. The patient was promptly relieved of his ulcer distress and experienced only moderate symptoms of gastric retention. The ulcer was no longer visualized at gastroscopic examination on September 6, but on October 7 a superficial ulceration could be seen. On November 4 gastroscopic examination revealed unequivocal malignant ulceration. Roentgen examination on September 4 was unsatisfactory, but on October 8 (fig 5 B) the ulcer was well visualized and, although larger and shallower, was thought to show no appearance of healing. The patient was urged to have a total gastrectomy but died of a cerebral accident at home a few days subsequently. Autopsy was not permitted. During the last few days of his life the patient's ulcer-like distress returned to a mild degree, although his insulin reaction postoperatively remained negative.

CASE 8—A 61 year old machinist had been bothered for sixteen years by vague, dull, epigastric pain, which had been much greater during the past two years. The relation of this distress to meals was inconstant. Roentgen examination was reported to have revealed an ulcer of the stomach two years previously, and since this time he had been on a modified medical management without much relief. Roentgen examination on admission (fig 6 A) showed a large ulcer crater on the lesser curvature. This was confirmed by gastroscopy. The lesion appeared to be benign. The twelve hour night gastric aspiration revealed 240 cc. of fluid with 24 units of free acid. At laparotomy on October 23 the lesion appeared to be benign. There was a firm palpable mass with a central crater high on the lesser curvature of the stomach with adherent overlying omentum. A subvagotomy section of the vagus nerves was performed with immediate relief of distress.

Roentgen examination on November 9 showed decrease in the size of the ulcer, as did roentgenograms taken on December 7 (fig 6B) Roentgen examination on Jan 7, 1947 (fig 6C), however, again demonstrated the ulcer on the lesser curvature. The patient was readmitted at this time, and studies of secretion revealed no evidence of incomplete vagotomy Total gastrectomy was advised but was refused by the patient, and he is still under observation

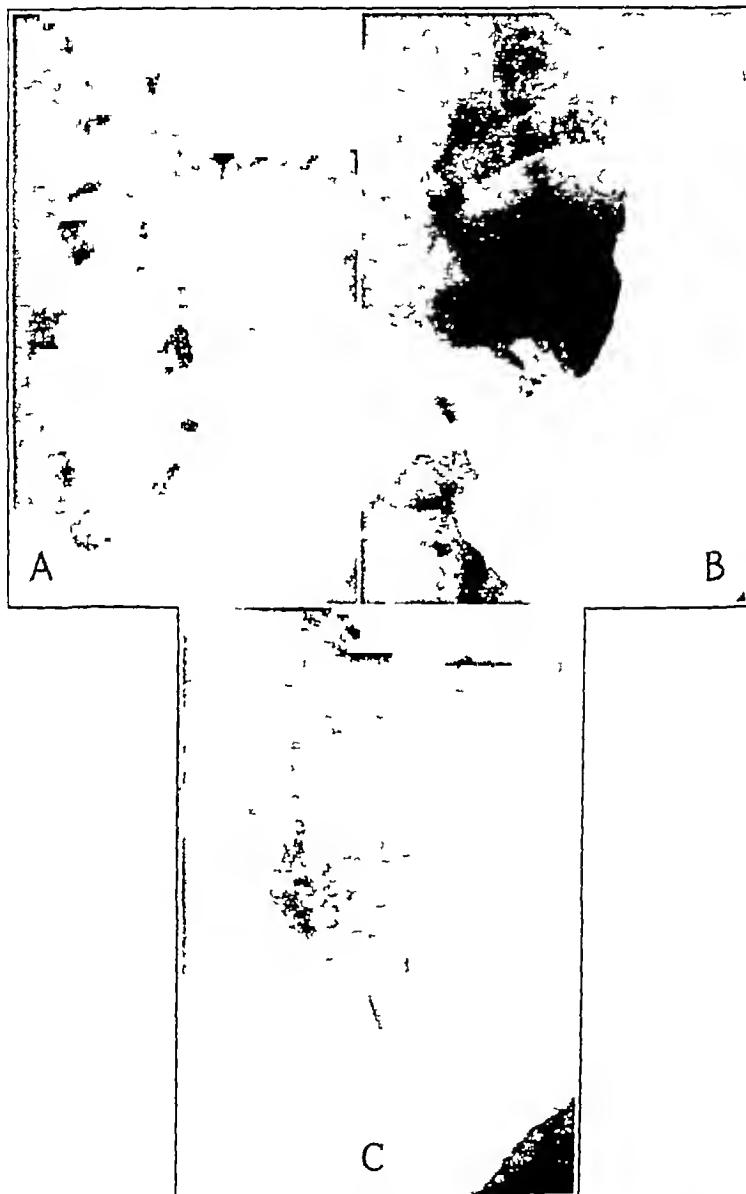


Fig 6 (case 8).—*A*, roentgenogram showing an ulcer crater on the lesser curvature of the stomach. *B*, roentgenogram showing a decrease in the ulcer crater of *A*, six weeks after gastric vagotomy. *C*, roentgenogram showing recurrent and probably malignant ulcer, eleven weeks after gastric vagotomy.

COMMENT

In this series of patients, all the ulcers that were unquestionably benign healed promptly after the total section of the vagus nerves. The reason for this in cases with coexistent duodenal ulcer is fairly evident, as all of the patients in this category secreted large quantities of highly acid gastric juice in the empty stomach. This hypersecretion was eliminated by the vagotomy, and the ulcers healed. The patients with benign gastric ulcer alone, however, without exception displayed a low volume of night secretion with low free acidity. Although the acid secretion in these patients was reduced after the section of the vagus nerves, it is difficult to understand how such a relatively small change in the acid secretion at such a low concentration could cause prompt healing of a large ulcer in the stomach. It is likewise difficult to account for the formation of an ulcer in the gastric mucosa, which is the most resistant tissue in the body to peptic digestion, as a result of this low concentration of free acid. The possibility can be considered that a high acid secretion existed prior to the formation of the gastric ulcer and that following the formation of the ulcer, a resultant or accompanying gastritis reduced the acid secretion. There is, however, little evidence to support this hypothesis. We have, in fact, 1 patient in whom a large gastric ulcer developed in spite of a known low acid secretion for several years. The fact that gastric ulcers heal after vagotomy, although there may be only a slight change in the concentration of acid in the gastric content, suggests both that other factors than peptic digestion alone may play a role in the formation of these ulcers, and that vagotomy has some effect on these factors. What factors exist that are known to be affected by vagotomy and which could influence the resistance of the gastric mucosa to peptic digestion? The only factor in addition to secretion affected by vagotomy for which we have definite evidence is gastric motility. In addition to trauma hypermotility might conceivably cause the removal of a protective coating of mucus from the surface of the mucosa, exposing the underlying epithelium to the action of peptic digestion. This factor might be altered by vagotomy. The possibility of other unknown and unconsidered factors is, of course, most likely. The fact remains that after total section of the vagus nerves a benign gastric ulcer usually heals and remains healed.

The treatment of gastric ulcer, however, is determined not so much by these considerations as by the fact that at the present time an accurate differential diagnosis between gastric ulcer and carcinoma cannot be made. Perhaps 20 per cent of lesions in the stomach that appear to be benign ulcers on the basis of the clinical picture and roentgen and gastroscopic examination prove to be carcinomas when studied by histologic methods. An exception to this statement must be made

for those cases with coexistent active duodenal ulcers, in which the incidence of carcinoma is considerably less than 1 per cent. Thus the presence of an active duodenal ulcer strongly suggests that the associated ulcer in the stomach is benign. We are of the opinion that these lesions can be treated satisfactorily by gastric vagotomy.

Should all other chronic ulcerating lesions in the stomach be treated by gastrectomy? The mortality following partial or subtotal gastrectomy is now less than 5 per cent. When, therefore, the lesion is in the antrum or body of the stomach and when a subtotal gastrectomy will suffice to remove it with some margin of uninvolved tissue, it seems wise to employ this procedure. Histologic examination will then determine the diagnosis, and the question of further treatment can be more intelligently considered. When, however, the lesion lies high on the lesser curvature near the esophagus, a resection to be more than a gesture would mean a total gastrectomy with possibly the removal of a portion of the lower part of the esophagus. A procedure of this magnitude carries with it an operative mortality of possibly 10 to 30 per cent and a definite digestive and nutritive disability in many of those that survive. It should not be employed unless the diagnosis of malignant growth is certain. It is in this group of gastric lesions in which vagotomy may find a field of usefulness. If the lesion is benign, section of the vagus nerves may bring about prompt healing in ulcers that have proved resistant to intensive medical management. On the other hand, if healing does not occur within a period of four to six weeks, the surgeon has additional evidence for the belief that the lesion is malignant and can undertake a total gastrectomy with a better conscience.

GASTRIC NEURECTOMY

Anatomic and Physiologic Studies with Favorable and Unfavorable Results in the Treatment of Peptic Ulcer

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D RAGSTEDT'S¹ report in 1946 on the section of vagus nerves in 54 cases of peptic ulcer with favorable results, similar reports by Grimson,² Ruffin and co-authors³ concerning 30 cases at Duke University, and by Moore and his associates⁴ concerning 12 cases at the Massachusetts General Hospital led us to study the problem of resection of vagus nerves, or, as we prefer to call the operation, "gastric neurectomy," from the anatomic, physiologic and chemical standpoint in 40

Read at the fourth annual meeting of the Central Surgical Association Chicago, Feb 22, 1947

From the Division of Surgery Mayo Clinic (Dr. Walters) and the Mayo Foundation

1 Dragstedt, L. R. Section of the Vagus Nerves to the Stomach in the Treatment of Gastro-Duodenal Ulcer, Minnesota Med 29 597-604 (June) 1946

2 In Grimson's most recent report (unpublished) on the results of the operation in 57 cases, he described disturbances in motility in 25. In 6 cases there was severe gastric retention which necessitated gastroenterostomy. This gave an incidence of secondary gastroenterostomy of 1 among each 7 patients who had not had a previous drainage operation.

3 Grimson K S Unpublished data Grimson K S Taylor, H. M., Trent, J C Wilson, D A and Hill H C The Effect of Transthoracic Vagotomy upon the Functions of the Stomach and upon the Early Clinical Course of Patients with Peptic Ulcer, South. M J 39 460-470 (June) 1946 Ruffin I M, Grimson, K S, and Smith, R C The Effect of Transthoracic Vagotomy upon the Clinical Course of Patients with Peptic Ulcer Gastroenterology 7 599-606 (Dec) 1946

4 Moore, F D, Chapman, W P, Schultz M D and Jones C W Transdiaphragmatic Resection of the Vagus Nerves for Peptic Ulcer New England J Med 234 241-251 (Feb 21) 1946

patients operated on by one of us at the Mayo Clinic up to Jan 15, 1947 (tables 1 and 2). Only brief reference will be made to 43 additional cases in which operation was performed by other surgeons at the clinic, for they will individually report on their results in detail later.

HISTORICAL DATA

Denervation of the stomach in the treatment of pain and peptic ulcer is not a new procedure, and an extensive and confusing literature has appeared since Brodie's⁵ first report in 1814. Early and late effects of denervation of the stomach have been confused, and the results of

TABLE 1—Our Cases to Jan 15, 1947

Operation, Type	Operation Performed for				
	Total Cases	Gastro-			
		Duodenal Ulcer	jejunum Ulcer	Gastric Ulcer	Gastritis
Gastric neurectomy only	14	10	2	2	0
Gastric neurectomy and gastroenterostomy	15	15	0	0	0
Gastric neurectomy with excision or resection	11	8*	5	8*	1
Total	40	28*	7	5*	1

* One patient had both duodenal and gastric ulcers

TABLE 2—Gastric Neurectomy All Cases to Jan 1, 1947

Operation, Type	Operation Performed for				
	Total	Gastro-			
		Duodenal Ulcer	jejunum Ulcer	Gastric Ulcer	Gastritis
Gastric neurectomy only	32	16	14	2	0
Gastric neurectomy with gastroenterostomy	30	30	0	0	0
Gastric neurectomy with excision of ulcer	18	5*	10	8*	1
Total	80†	51	24	5*	1

* There were both duodenal and gastric ulcers in 1 case

† Three additional patients were operated on up to Jan 15, 1947, but were not included, at the request of the Division of Biometry and Medical Statistics

section of the gastric and vagus nerves of man have been compared indiscriminately with those of lower animals.

Latarjet⁶ after division of the gastric nerves in dogs found that (1) no grave effects followed, (2) the tonicity of the stomach was reduced, dilatation occurred and emptying time of the stomach was delayed from a normal of two to seven hours and (3) the gastric acidity was decreased, the secretion of mucus was increased and trophic lesions did not occur. He and Pauchet operated on 6 patients who had gastric

⁵ Brodie, B C, cited by Hartzell⁷

⁶ Latarjet, A Note préliminaire sur l'innervation et l'enervation de l'estomac, Lyon med 130 166-167, 1921. Resection des nerfs de l'estomac Technique opératoire résultats cliniques, Bull Acad de méd, Paris 87 681-691, 1922

ulcers, 1 died from carcinoma later. In commenting on the results of the operation on the other 5 Latarjet stated that all had been relieved of their symptoms, had gained weight and had an increased appetite. In all 5 cases gastroenterostomy was performed at the time of the gastric denervation in the belief that it would prevent recurring ulceration in the presence of gastric stasis, for Greggion was able to produce a high incidence of gastric ulceration in rabbits by denervating their stomachs and adding to their food with a high fibrous content. The stomach of the rabbit differs from that of dog or man and, therefore, is a paunch.

In spite of this encouraging early result reported by Latarjet in 1922, a search of the subsequent French literature failed to reveal any further reports of studies or cases in which denervation of the stomach was employed.

In 1929 Hartzell⁷ studied the effects of intrathoracic resection of the vagus nerves on 8 dogs. The immediate results were similar to some of those described by Latarjet, they consisted of a total abolition of psychic secretion (cephalic phase), pronounced and constant reduction of the quantity of free hydrochloric acid and of the total acids and an increase in the p_{H} of the gastric secretion.

Vanzant⁸ studied Hartzell's dogs and some others two and one-half years later. She found that free acid was present in all but 1 of Hartzell's original group. The effects of vagotomy on motility of the stomach were inconstant. In 4 of the dogs which she studied, emptying of the stomach was delayed, 2 had hypermotility with a tendency to diarrhea and emesis, and 3 had no change in gastric emptying time. Later results revealed the motility of the stomach of 7 of the 10 dogs she studied to be essentially normal.

ANATOMIC STUDIES

Our anatomic dissections of the gastric nerves were made on 56 men, 44 women and 11 children during the course of postmortem examinations. In ninety-two of the specimens from adults a rather regular pattern was followed in forming discrete nerve trunks from the esophageal plexus. In 8 cases, it was impossible to isolate two distinct trunks at any point, since the branches were numerous intercommunicated and failed to follow a uniform pattern.

These anatomic studies indicated, therefore, that the gastric nerves could be located and successfully resected near the diaphragm by either a transabdominal or a transthoracic approach in approximately 92 per cent of the cases and that possibly most if not all of the branches in the remaining 8 per cent also could be located in the same way.

⁷ Hartzell, I. B. The Effect of Section of the Vagus Nerves on Gastric Acidity, Am J Physiol 91: 161-171 (Dec) 1929.

⁸ Vanzant, F. R. The Late Restoration of Gastric Acid after Thoracic Vagotomy in the Dog. Gastroenterology to be published.

It is our belief that the abdominal approach is preferable to the transthoracic one for the following reasons 1 It permits exploration of the contents of the abdomen, which may be necessary, as a Meckel diverticulum was found in 1 case and no ulcer in another 2 It permits examination of the ulcer and its removal if it is a gastric ulcer and is suspected of being malignant 3 It permits some type of drainage operation of the stomach if an obstructive duodenal ulcer is present or a duodenal ulcer is present that is likely to become obstructive, when gastric atony occurs after gastric neurectomy 4 It also is useful in cases in which a gastrojejunal ulcer has followed gastroenterostomy, for in many cases repeated ulceration of the stoma has resulted in obstruction and reactivation of the duodenal ulcer In such cases, removal of the gastrojejunal ulcer and disconnection of the gastroenteric anastomosis are necessary in addition to gastric neurectomy 5 It permits pyloroplasty if obstruction of the duodenum has resulted from reactivation of the duodenal ulcer or from its healing after gastroenterostomy We have tried to prevent post-operative gastric stasis and retention of secretion by anticipating that it may occur and compensating for it by a drainage operation on the stomach at the time of gastric neurectomy rather than later, and we have succeeded rather well in this purpose

Gastric neurectomy has been performed without any other associated operative procedure in only 14 of 40 cases in which the operation has been carried out by one of us (W W) and in only 19 of the 43 cases in which it was performed by other surgeons at the clinic

GASTRIC NEURECTOMY OUR SERIES WITHOUT OTHER GASTRIC OPERATIONS

The results in 13 of the 14 cases in which one of us performed the operation without other surgical procedures on the stomach have been satisfactory as far as measured by relief of pain, by reduction of gastric acidity and in general by reduction in gastric secretion (tables 1, 3 and 4)

Ten of these operations were performed for duodenal ulcer, two for gastric ulcer and two for gastrojejunal ulcer One death occurred one hour after the patient had had an uneventful transabdominal gastric neurectomy Coronary insufficiency was confirmed as the cause of death at necropsy In this case the duodenal ulcer was producing intractable pain and the serious risk of the operation was appreciated by the surgeon and the patient In 8 of the 10 cases of duodenal ulcer reductions in acidity occurred, in 4 of these achlorhydria developed Eight of the patients had insulin tests, six tests revealed a flat or decreasing curve of secretion of gastric acid and two a rise in secretion of gastric acid

Disturbances of motility with retention occurred in 4 of the cases, in 1 of which intermittent aspirations were required from the fourth

to the ninth day, in the remaining 3 considerable retention of secretion and atony of the stomach were demonstrated on roentgenologic examination.

3—Our Cases from the Report of Nov 1, 1946 to Jan 15, 1947 (Included in the Total of Forty Cases)

Case	Lesion	Total and Free Acids		Minimal Blood Sugar Mg per 100 Cc	Curve of Insulin Test	Roentgenologic Findings	Results
		Before Operation	After Operation				
Gastric Neurectomy with No Other Operation							
1	Perforated duodenal ulcer	80/60	28/12	26	Downward	Atony of stomach	Good relief
2	Duodenal ulcer	78/51	26/10	35	Downward	Soon after operation, duodenal ulcer present	Good relief
3	Duodenal ulcer	None	60/48	17	Upward	Retained secretion, pylorospasm	Good relief
4	Duodenal ulcer	44/36					Died 1 hr after operation, of coronary insufficiency
Gastric Neurectomy with Simultaneous Gastroenterostomy							
5	Obstruction, duodenal ulcer	86/76	24/0	42	Downward	Nonsignificant gastroenterostomy	Good relief
6	Obstruction, duodenal ulcer	80/72	28/16	26	Downward		
Gastric Neurectomy with Simultaneous Gastric Resection							
7	Obstruction, duodenal ulcer	60/44	38/0	60	Flat	Atony with retention of secretion, barium remained in stoma	Early relief fulness no return of pain

TABLE 4—Free Gastric Acidity in Relation to Type of Gastric Operation in Our Cases

Type of Operation	Total Cases	Gastric Acidity Before Operation		Gastric Acidity After Operation	
		Determinations Cases	Mean Value, Units	Determinations, Cases	Mean Value Units
Gastric neurectomy only	16	10	374	10	24
Gastric neurectomy and gastroenterostomy	17	14	71	1	115
Gastric neurectomy and resection					
Gastrojejunostomy					
Gastric ulcer	1	4	500	1	164
Duodenal ulcer	2	2	500	2	60
Gastritis*	1	3	420	1	6
Total	13	10	71	10	24
Grand total	4	4	47	4	24

In the 2 cases in which small gastric ulcers were present no hydrogen developed after the operation. Insulin tests gave negative results. In 1 of these patients atony of the stomach developed which continued

for at least eight weeks. Although this patient was relieved of pain after his operation, he complained of discomfort and a feeling of fullness in his stomach when he had eaten a small amount of food at mealtime. At the time of reexamination at the clinic the stomach was so dilated and there was so much secretion that the roentgenologist was unable to determine whether the gastric ulcer had healed or not. Unfortunately gastroscopic examination was not made, but one will be at the patient's next visit.

WITH OTHER GASTRIC OPERATIONS

Duodenal Ulcer.—In 15 cases in which duodenal ulcers were present gastroenterostomy (table 1) was performed simultaneously with gastric neurectomy. In 7 of this group relative achlorhydria developed, in 4 reduction of gastric acidity was marked, and in 1 no reduction occurred. In 1 of the remaining 3 no preoperative studies of gastric acidity were performed, but postoperative studies revealed total acidity of 34 and free acid of 22 (Topfer's method). In 2 cases no postoperative studies of gastric acidity were carried out.

Troublesome disturbances of gastric motility developed in 4 of these cases. In 1, the retention continued for twenty-six days, and a jejunoojejunostomy was necessary. However, the gastroenterostomy in this case was an anterior one.

One patient had such a degree of abdominal distention from the fifth to the seventh day after operation that an intestinal obstruction was thought likely, and roentgenologic examination indicated that it was present. Abdominal exploration revealed that the entire gastrointestinal tract was filled with fluid and gas, and 800 cc of sterile straw-colored fluid was present in the abdominal cavity. The patient's gastrointestinal motility returned to within normal limits in a few days after continuous aspiration of the gastrointestinal secretions by an indwelling Wangensteen suction tube.

Another patient had retention daily. Occasionally a maximum of 2,000 cc was found. The quantity of retained secretions decreased gradually until the fourteenth day after operation. Six months later the patient reported by letter that he had a recurrence of his symptoms of ulcer with vomiting.

Gastric Ulcer.—Three patients had large gastric ulcers. All were high on the posterior wall of the stomach and had perforated onto the pancreas. Partial gastrectomy for removal of the ulcers would have necessitated removal of most of the stomach. It seemed best, therefore, to excise the ulcers and to see what the effects of gastric neurectomy would be. In 1 of these cases a recurring gastric ulcer developed with severe ulcer symptoms, including bleeding and associated anemia. In the second case complete relief from pain occurred after operation while

an unrestricted diet was being given, but the patient complained of frequent belching of foul gas for four months Roentgenologic examination gave evidence of a dilated stomach with spasm in the prepyloric area and hypomotility of the small intestine There was so much secretion at the end of a five hour period that the roentgenologist could not tell whether gastric ulcer had returned or not Gastroscopic examination revealed no recurrence of his gastric ulcer

Gastrojejunal Ulcer—Five patients were treated for gastrojejunal ulcers by gastric neurectomy and additional procedures (table 1)

In 1 of these cases the ulcer had occurred after partial gastrectomy was done elsewhere Its large crater was on the transverse colon It seemed advisable in this case to resect the stomach to remove the ulcer, and to perform a gastric neurectomy rather than to do the latter procedure alone because of the uncertainty of whether the ulcer would heal and of whether it would produce obstruction at the stoma Achlorhydria developed after operation Unfortunately an insulin test was not done in this case No clinical retention was noted and roentgenologic examination revealed normal motility There was good relief of symptoms

Two patients had gastrojejunal ulcers of considerable size with deformities of the gastroenteric stoma and deformities of the duodenum as a result of the healing of their duodenal ulcers After the gastroenteric anastomosis was disconnected, the gastrojejunal ulcer was removed in each case and pyloroplasty was performed for the relief of the duodenal obstruction Achlorhydria did not develop in either of these cases in spite of negative reactions to the insulin tests It will be interesting to see what the future course of these 2 patients will be, for experience has shown that there is a 60 per cent recurrence of the duodenal ulcer in cases in which the procedure just described has been performed without associated gastric neurectomy In 1 of these 2 cases gastric retention of secretion occurred from the fourth to the sixth day In 1 of these cases pylorospasm was noted on roentgenologic examination, in the other, a slightly atonic stomach was found

In the remaining 2 cases the gastroenteric anastomosis and the gastrojejunal ulcers were removed and reconstruction of the stomach and jejunum was carried out In 1 of these 2 cases achlorhydria developed In the other case a total gastric acidity of 20 units and free hydrochloric acid of 6 units were observed after operation but no preoperative studies of gastric acid were made Inulin tests in both cases were negative in result Neither had disturbances of motility

In the cases of gastrojejunal ulcer the immediate results of the operation have been satisfactory

GASTRIC NEURECTOMY OTHER CLINIC SURGEONS' SH WITHOUT OTHER GASTRIC OPERATIONS

Gastric neurectomy without other surgical procedures has been performed in 19 cases by other surgeons at the clinic. In 14 cases the operation was done transthoracically and in 5 transabdominally.

Transthoracic Approach Five patients who had duodenal ulcers and 9 who had gastrojejunal ulcers were operated on transthoracically. Eleven had preoperative and postoperative studies of gastric acidity. In 5 of the cases of gastrojejunal ulcer and in 1 of duodenal ulcer achlorhydria developed. In 2 cases of duodenal ulcer and in 1 of gastrojejunal ulcer no reduction of acidity occurred. Postoperative roentgenographic studies were made in 8 cases. In 2 of the cases of gastrojejunal ulcer evidence of jejunitis continued. In one case achlorhydria developed but no reduction of acid occurred in the other. Four patients had delayed emptying of the stomach. In 1 patient it was so prolonged (over 6 months) that anterior gastroenterostomy was performed. This will be referred to later.⁹ In another, pain from a duodenal ulcer caused night pain which required foods and alkali for relief has continued.

Two patients had troublesome diarrhea after operation, one had a return of symptoms of ulcer and the other had nausea and vomiting in addition. One patient died after a convulsion on his postoperative day.⁹

Transabdominal Approach Two patients who had duodenal ulcers and 3 who had gastrojejunal ulcers underwent transabdominal neurectomy. Only 1 of these patients had complete relief of symptoms. One of the patients who had a duodenal ulcer had symptoms of belching and vomiting four months after operation, and, although he had no ulcer pain, a roentgenogram showed a persisting duodenal ulcer. One of the patients who had a gastrojejunal ulcer had persistent symptoms of ulcer with disturbances of gastric motility which included aspiration for one month after operation. Roentgenologic examination revealed evidence of a poorly functioning gastroenteric stoma, distortion of the jejunum, and the presence of a gastrojejunostomy which could not be ruled out.⁹

WITH OTHER GASTRIC OPERATIONS

In 24 cases additional gastric operations were performed simultaneously, in 19 for duodenal ulcer and in 5 for gastrojejunal ulcer.

Duodenal Ulcer—Sixteen of the patients who had duodenal ulcers had associated gastroenterostomy and 3 had pyloroplasty. In the group who underwent gastroenterostomy preoperative and operative studies of gastric acidity were carried out. Nine patients

⁹ This case will be referred to again in the section on "Recurrence or Failure of Ulcer to Heal Both Series."

marked reduction of gastric acidity, and 4 of these had achlorhydria. Two had no reduction of acidity. Temporary moderate disturbances of motility were noted in 5. One of the patients had a perforating duodenal ulcer and died on the fourteenth postoperative day.¹⁰

In all of the 3 cases in which pyloroplasty was performed gastric acidity was reduced considerably after operation from a high preoperative level, but in one of these cases clinical evidence of disturbance of

TABLE 5.—Failure of Ulcer to Heal After Gastric Neurectomy

Case	Lesion	Gastric Neurectomy	Other Operation	Gastric Acids		Roentgenologic Observations	Results*
				Before Operation	After Operation		
6	Gastric ulcer and duodenal ulcer	Trans thoracal	Excision through diaphragm	64/52	40/76	Persistent gastric ulcer	Resection of stomach*
9	Duodenal ulcer	Abdominal	None	74/56	40/20	Duodenal ulcer 3 mo after operation	Fulness, bloating, vomiting, no pain, some diarrhea
10	Duodenal ulcer	Trans thoracal	None	70/56	59/50	Retention with obstruction at pylorus	Retention gastroenterostomy 2 mo after operation, trouble—some irritation 1 mo after gastroenterostomy
11	Gastrojejunai ulcer	Trans thoracal (elsewhere)	None		40/25	Dilated jejunal loop, gastrojejunitis	Several hemorrhages, resection of stomach, large gastrojejunai ulcer
12	Gastrojejunai ulcer, jejunitis	Trans thoracal	None	100/80	60/48	Poor function gastrojejunai ulcer could not be ruled out	Return of pain 2 mo after operation, diarrhea
13	Gastrojejunai ulcer	Trans thoracal	None	40/20	11/0	Gastrojejunitis	Diarrhea and nausea
14	Gastritis	Abdominal exploratory	Exploratory laparotomy	51/42	80/0	Atony of stomach, peristalsis, trituration, no contraction	Symptomatic relief

In ulcer test was negative in result.

gastric motility was present and in another pain was occurring at night at the time of dismissal.

Gastrojejunai Ulcer—Resection of the stomach was performed in 1 case of bleeding gastrojejunai ulcer. Transthoracic resection of the vagus nerves had been performed elsewhere six and one-half months previously, without benefit to the ulcer.¹⁰ Excision of the gastrojejunai ulcer and disconnection of the gastroenteric anastomosis were per-

* This case will be referred to again in the section on "Recurrence of Lesions or Failure of Ulcer to Heal." Both Sets e."

formed in 3 cases, in 2 of which pyloroplasty was performed also One patient, who died at home three months after operation from a coronary occlusion, had a fistulous opening into the colon closed -

RECURRENCE OF ULCER OR FAILURE OF ULCER TO HEAL BOTH SERIES

One of the patients operated on by one of us (W W) had a recurring gastric ulcer (table 5) This patient, a Jew 67 years of age, had had a gastrojejunal ulcer which had been removed at a previous operation when the gastroenteric stoma was closed Subsequent to the operation, achlorhydria developed The insulin test (table 6) gave negative results, and disturbances of gastric motility were not pronounced, although slight retention was noted soon after gastric neurectomy Roentgenologic examination on Oct 17, 1946 disclosed a return of the gastric ulcer with an atonic stomach This resulted in spite of a careful and well controlled medical regimen which was continued for

TABLE 6—Results of Insulin Test in a Case of Recurring Gastric Ulcer

	Fasting	Time After Injection of Insulin, Min			
		15	30	45	60
Sept 18, 1946					
Blood sugar, mg /100 cc	103	89	68	48	45
Total acid, units	26	12	12	10	10
Free hydrochloric acid, units	10	0	0	0	0
Amount of gastric secretion, cc	30	10	15	30	40
Jan. 7, 1947					
Blood sugar, mg /100 cc	105	118	72	47	35
Total acid, units	26	8	10	10	0
Free hydrochloric acid, units	10	0	0	0	0
Amount of gastric secretion, cc	45	8	10	20	60

five and one-half months In January 1947 the patient complained of pain in the region of the left supraspinatus muscle and down his left arm This pain was thought to be due to extension of the inflammation from the ulcer to the diaphragmatic portion of the peritoneum The results of insulin test (table 6) were essentially the same as at the time of the previous examination except that the curve was even flatter A histamine test resulted in a marked elevation in acids On January 13 Dr Waugh performed a Hofmeister-Polya resection of the stomach, a benign gastric ulcer with a crater 3.5 cm in diameter was removed with the resected portion of the stomach

Two cases (table 5) in which our colleague, Dr Priestley, performed the operations are worthy of mention In 1 of these cases (case 11, table 5) transthoracic gastric neurectomy had been performed elsewhere for gastrojejunal ulcer, hemorrhage from the ulcer had occurred ten hours after the operation and again several weeks later When the anastomosis was taken down and the patient's stomach was resected, an active gastrojejunal ulcer with a crater and pronounced

jejunitis was found. In the second case (case 10) Dr Priestley felt it necessary to perform a drainage operation on the stomach twelve days after transthoracic gastric neurectomy because of failure of the stomach to empty properly. As much as 500 cc of gastric secretion was removed at one time in this case before the second operation. An active duodenal ulcer was found at operation and the pylorus was patent. Anterior gastroenterostomy was performed, but retention of gastric secretion in larger amounts began on the twelfth day following operation and continued for more than thirty days. Unfortunately it was not possible to perform the Hollander insulin test in either of these cases to determine whether all branches of the vagus nerves were divided.

In a recent report by Colp¹¹ of 33 cases of ulcer treated by supradiaphragmatic resection of the vagus nerves, gastric resections were required in 4 from two to seven months later. Disturbances in motility made resection necessary in 3 and persistent symptoms of ulcer in the other case. Of the 33 patients, he considered only 18 as well. One patient had recurring hemorrhages thirteen months after operation, and 1 died from hemorrhage into the left adrenal gland fourteen days after operation.

In another case of duodenal ulcer in which transabdominal gastric neurectomy was performed by one of our colleagues, relief of pain was obtained but bloating, belching and vomiting continued for four months after operation and roentgenograms indicated a persisting duodenal ulcer.

One of the patients who had a transabdominal gastric neurectomy for a gastrojejunal ulcer had persistent symptoms of ulcer with disturbances of gastric motility which required aspiration for one month after operation. Roentgenoscopic examination disclosed a nonfunctioning gastroenteric stoma with distortion of the jejunum. A gastrojejunal ulcer could not be ruled out.

Schist¹² has told us of 1 of his patients who had duodenal ulcer which failed to heal after resection of the vagus nerves. Subsequent partial gastrectomy was made necessary because of a continuation of symptoms of ulcer and hemorrhages. The presence of an ulcer was proved at the time of operation.

operative symptoms in this case Postmortem examination revealed an unsuspected perforation of the duodenal ulcer and subdiaphragmatic abscess In another case, in which gastric neurectomy, cholecystectomy and appendectomy were performed, the patient died after a convulsion on the fourth postoperative day Unfortunately consent for postmortem examination could not be obtained Another death from coronary disease was reported to us by the patient's physician in his home locality It occurred three months after gastric neurectomy for gastrojejunocolic fistula in which the fistula into the colon was closed at the time of operation

Recently Weeks and his associates,¹³ working at Bellevue Hospital, reported 2 deaths following transthoracic resection of the vagus nerves One of these deaths was due to an unsuspected perforation of the duodenal ulcer seven weeks after operation, and the other death occurred on the operating table when traction was being placed on the left vagus nerve In the former case, resection of the left splanchnic nerve had been done at the time of the transthoracic resection of the vagus nerves and that of the right splanchnic nerve a week previous to the perforation of the ulcer In the second case the death was of a cardiac type, but no necropsy was done

COMMENT AND SUMMARY

Our studies on gastric neurectomy indicate that the results are inconstant, variable and in most cases unpredictable The relief of pain obtained may be the result of the release of gastropasm and a reduction in gastric acidity as a result of the interruption of cephalic stimulation The expense of this relief of pain is dilatation of the stomach with frequent troublesome retention of gastric secretion and in some cases remnants of food Moreover, that relief of pain is not the result of healing of the ulcer must be considered, since in 1 of our cases unsuspected acute perforation of duodenal ulcer developed A similar case has been reported by Weeks and his associates¹³

In 1 case a gastric ulcer recurred, in other cases failure of the ulcers to heal has been demonstrated pathologically at subsequent operations necessitated by a continuation of bleeding or a marked degree of gastric retention which interfered with the patient's nutritional state

Reduction in gastric acidity, although it has occurred in most cases, is inconstant in others, and the disturbances of motility of the stomach and small intestine are frequent after operation In some cases these disturbances are temporary, and in others are prolonged, persistent and troublesome to the patient In such cases, patients have complained of frequent belching of foul-smelling gas and fulness and bloating after

13 Weeks C, Ryan, B J, and Van Hoy, J M Two Deaths Associated with Supradiaphragmatic Vagotomy, J A M A 132 988-990 (Dec. 21) 1946

meals, and a few have complained of nausea and diarrhea. As has just been mentioned, subsequent operations have been necessary in some cases to remove the persistent ulcer or to provide drainage.

There have been 3 hospital deaths in the 83 cases. Although 2 of these could be directly attributed to cardiovascular accidents, 1 patient died of unsuspected perforated duodenal ulcer with a subdiaphragmatic abscess. Gastroenterostomy had been done at the time of the gastric neurectomy. Another patient died from a coronary occlusion at home three months after the closure of a gastrojejunum colic fistula.

In evaluation of the results of the operation it must be proved that an ulcer is present and that the gastric nerves have been completely sectioned. It is our opinion that the best approach in most cases in which gastric neurectomy is contemplated is by means of a transabdominal incision, for this approach permits exploration of the gastrointestinal tract and such procedures as are necessary to supplement the gastric neurectomy. The greatest field of usefulness for the operation seems to be in the treatment of ulcers after partial gastrectomy and in certain cases of nonobstructive duodenal ulcers in which the cephalic phase of gastric secretion is marked and pain is intractable.

In view of the inherent ability of the gastrointestinal tracts of human beings, like those of animals, to regain through compensatory mechanisms their function after operative procedures which disturb the neuromuscular continuity, and in view of the fact that restoration of gastric acidity and gastric motility has occurred within two years in dogs in which gastric neurectomy has been performed, the possibility of such a return in human beings must be kept in mind.

For the time being the operation of gastric neurectomy will have to be considered as in the investigative stage.

Note.—Since this paper was written 1 patient has died at home eight months after operation from gangrene of the terminal part of the ileum. This patient is the one who had abdominal distention from the fifth to the seventh day after gastroenterostomy and gastric neurectomy at which time abdominal exploration was performed but no obstruction was found. The gastrointestinal motility then returned to normal after continuous gastric aspiration.

Another patient, the one who had retention for twenty-six days after anterior gastroenterostomy and gastric neurectomy and then underwent peritonitis, now has a gastrojejunum ulcer. His negative insulin tolerance (A 1 = 5.104%) showed that all branches of the vagi to the stomach had been resected.

RESECTION OF THE VAGUS NERVES FOR ULCER AN INTERIM EVALUATION

I Operative Technic and Hospital Management

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RESECTION of the vagus nerves for ulcer, like any other application of autonomic surgery, may be considered to embody three rather distinct areas for study and development. The first of these concerns the technical procedure itself, its extent, its intrinsic surgical complications and the immediate hospital morbidity and mortality. The second area embodies the physiologic response of the patient. No autonomic nerve can be interrupted, be it the presacral plexus, the lumbar sympathetic, the splanchnic nerve, or the vagus, without producing physiologic changes, an understanding of which is absolutely essential to intelligent clinical application of the procedure. The third area in this field involves close examination of the clinical end results. Clinical results may be extremely variable in their degree of dependence on the first two factors.

In this paper it is my wish to outline the technical procedures which my colleagues and I have employed in vagus resection for ulcer as well as the hospital management of patients. We previously described the physiologic effects of the operation.¹

The clinical results in the patients operated on to date will be described in the subsequent paper.² The study of resection of the vagus nerves at the Massachusetts General Hospital comprises at the present time a group of 84 patients who have had this operation performed. There are 4 patients in this group who have had resection of the vagus nerves for diseases other than peptic ulcer. Six patients have been operated on too

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb 22, 1947

1 Moore, F D , Chapman, W P , Schulz, M D , and Jones, C M (a) Trans-diaphragmatic Resection of the Vagus Nerves for Peptic Ulcer, New England J Med 234 241-251 (Feb 21) 1946, (b) Resection of the Vagus Nerves in Peptic Ulcer Physiologic Effects and Clinical Results, with a Report of Two Years' Experience, J A M A 133 741-748 (March 15) 1947

2 Moore, F D Vagus Resection for Ulcer An Interim Evaluation, II Clinical Results, Ann Surg, to be published

recently to be of value in any consideration of clinical effects. The remaining 74 patients will form the subject of this discussion.

I SURGICAL TECHNIC

1 Essential Conditions.—The operative technic used in this study has been developed to include the following essential features:

(a) A thorough dissection should be done with adequate exposure under satisfactory conditions of lighting and availability of the field. These conditions are best satisfied by a thoracic approach.

(b) The only way that we know of definitely establishing the fact that all of the fibers of the trunks of both vagus nerves have been sectioned is to follow the nerves downward to their point of decussation on the stomach wall.

(c) The gastrointestinal tract is allowed to retain its normal continuity, providing that previous surgical treatment has not been given. No gastroenterostomy is carried out at the time of resection of the vagus nerves or afterward unless clinical necessity demands it—a rarity in our experience. The importance of this seems self evident. Placing jejunal mucous membrane in the stomach has been a source of difficulty since the introduction of posterior gastroenterostomy as a treatment for ulcer many years ago. Jejunal mucosa is much more vulnerable to gastric secretion than duodenal. In addition, posterior gastroenterostomy alone will confer satisfactory results on the healing of ulcers in a certain fraction of cases. If one concedes that resection of the vagus nerves is also a useful operation, it is then clear that the performance of a posterior gastrojejunostomy with resection of the vagus nerves will confuse the interpretation of the clinical results.²²

(d) Steps to prevent regeneration should be taken. This is accomplished by resection of a portion of the nerves and enclosure of the proximal ends in some sort of an impermeable sheath.

the characteristics of bleeding ulcers, especially painless bleeding ulcers, to heal rapidly once the bleeding has ceased. Two experiences which we have had with patients who have bled massively from the gastrointestinal tract within a week of vagus resection have led us to believe that in patients who have been bleeding recently, resection of the vagus nerves should be employed after the ulcer has been given a period of medical management.

In the case of painful, intractable ulcer without obstruction most characteristic of this group, attention is directed to the patient's general status relative to anemia, hypoproteinemia, malnutrition, renal stones, alkalosis or chronic disease of the lungs. In most cases an overnight secretion test by multiple sampling followed by an insulin test is carried out to provide a base line for future study. We have not found these tests to be of value in the selection of patients or in the prediction of results, they are omitted if the patient's clinical condition (i.e., severe pain on fasting) contraindicates them.

Either just before or just after the induction of anesthesia, a Levin tube is inserted into the stomach. This is useful in the mobilization of the esophagus and is also used postoperatively.

3 Anesthesia and Operative Technique—Anesthesia by intratracheal administration of gas-oxygen-ether has been used in all the patients who have had this operation. It produces conditions satisfactory for the surgeon and has been followed by a remarkably low incidence of pulmonary complications.

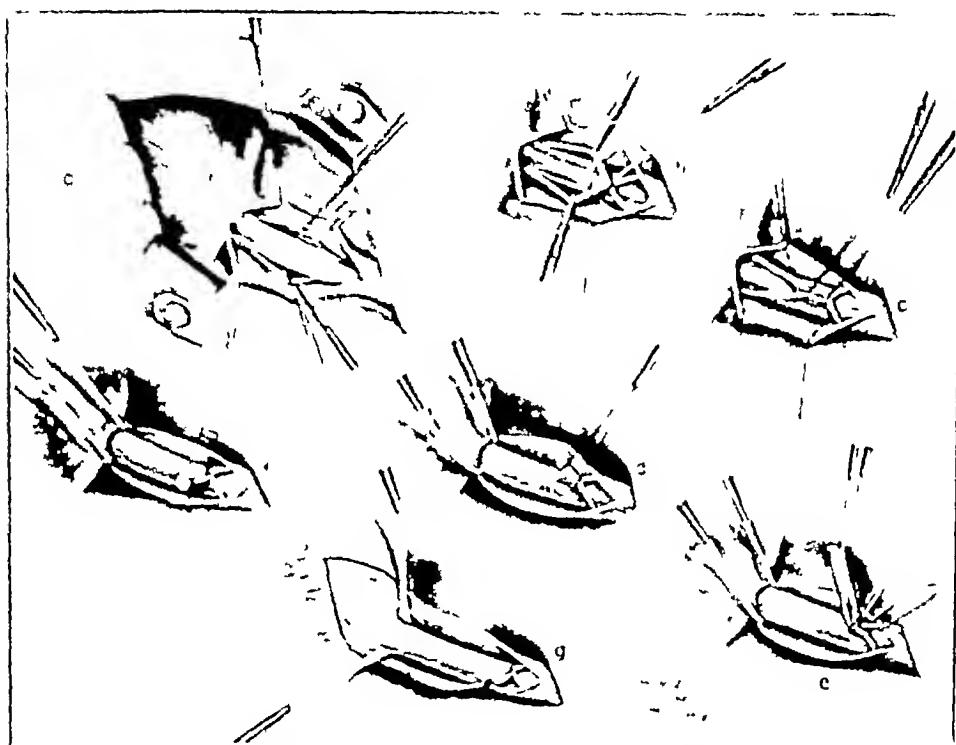
The chest is opened through the bed of the eighth, ninth or tenth rib, depending on the conformation of the patient. It is helpful to consult a roentgenogram of the patient's chest and to select the rib which in midaxilla is opposite the dome of the diaphragm.

After the chest has been opened, the mediastinum is entered by severing the inferior pulmonary ligament. Care should be taken to preserve the mediastinal reflection of the parietal pleura, as it greatly facilitates closing the mediastinum. In our early cases the esophagus was freed throughout its entire circumference and placed on traction during dissection of the nerves. We have since found that this is unnecessary and that a much more facile dissection can be carried out if the esophagus is allowed to drop back into the mediastinum as soon as the nerve trunks are picked up. In this fashion it is necessary to interrupt less of the esophageal blood supply.

There is considerable variability in the anatomic arrangement of the major branches of the vagus nerves. In the minor details of branching and arborization there is even greater variability. The important single anatomic fact remains that there are two vagus nerves running down along the esophagus to the stomach in the vast majority of patients. When the diaphragm is opened in a large series of cases, the truth of this

assertion becomes increasingly evident. One finds that there are two arborizations of the vagus nerves on the stomach wall, not more than two and not less than two. Above this area (in and immediately above the diaphragm) there are variable arborizations and anastomotic branches running between the two nerves, but the constancy of decussation on the stomach wall in itself provides adequate justification for dissecting the nerves down to their point of decussation. It is by this maneuver only that one can be assured of sectioning all the nerve fibers.

Two recent studies have clarified some of the untoward problems involved though the authors have come to quite different conclusions.



Diagrammatic sketch of operative technic employed in thoracic vagus resection. No effort is made to portray in detail the variable anastomotic branches of the vagus nerves above the diaphragm. (a) The chest having been opened through the bed of the ninth rib, the mediastinum is opened, and the two nerves identified. (b) and (c) The two nerves are sutured together at two points 2 cm apart. (d) The nerves are severed below the distal suture. (e) The proximal end of a silk cylinder is sutured to the proximal suture on the nerve trunks. (f) The silk cylinder is divided and ligated distal to the cut ends of the enclosed nerves. (g) The silk cylinder is sutured on or into the pleura so that there is no tension in the nerves. The diaphragm is opened (this step can be dispensed with if a slack hiatus permits delivery of the upper part of the stomach into the chest). The nerves are dissected downward to the point where they broaden out and divide into multiple fibers for decussation into the subserous layers of the stomach. They are divided at that point, diaphragm, mediastinum and chest are closed with interrupted silk sutures.

from their dissections Walters and his group^{2b} studied 100 adult subjects and found that 64 had well formed, common vagus trunks, 7 had extensive plexuses, but these nerves joined as well defined trunks before decussating on the stomach, 21 had long discrete trunks, characterized by few intercommunications, and the remaining 8 had atypical branches which left the trunks in the thorax. Despite the authors' conclusion that 10 per cent of the dissections disclosed patterns which were "not uniform" in the thorax, they concluded that the subdiaphragmatic approach is satisfactory. Miller and Davis³ dissected 13 cadavers, found essentially the same conditions, and concluded that a supradia-phragmatic operation is preferable. This conclusion would seem well warranted by the findings of atypical branches in about 10 per cent of the cases in the thorax.

This anatomic point is emphasized because no amount of dissection in the mediastinum can replace the downward tracing of the nerve trunks to their major arborization on the stomach wall as a means of positively identifying and removing the total nerve mass. Likewise, no subdia-phragmatic dissection will reveal the atypical mediastinal branches which occur in 8 to 10 per cent of cases, as described by Walters and his co-workers.⁴ Though one may find variable mediastinal branches, downward dissection shows that these branches arrange themselves into two trunks prior to decussation in the gastric subserous layers. For this reason the diaphragm has been opened in the majority of cases, in occasional patients the diaphragmatic hiatus is sufficiently patent so that the gastric decussation can be identified without incising the diaphragm.

The two nerves are sectioned about 3 inches (7.6 cm) above the diaphragm and enclosed in a silk cylinder, as shown in the figure. They are dissected downward to their point of arborization on the stomach wall, where they are again sectioned at the point where the nerve spreads out to divide into filaments in the seromuscular coat.

The circumference of the esophagus is checked for small fibers which plunge into the muscular walls and which may be divided at this point.

^{2b} Bradley, W F, Small, J T, Wilson, J W, and Walters, W Anatomic Considerations of Gastric Neurectomy, *J A M A* **133** 459-461 (Feb 15) 1947

³ Miller, E M, and Davis, C B, Jr An Anatomic Study of the Vagus Nerves, *J A M A* **133** 461-462 (Feb 15) 1947

⁴ We have not routinely employed any of the available cholinergic drugs (Machella, T E, Hodges, H R, and Lorber, S N The Restoration of Gastric Motility by Urethane of B-Methyl Choline After Section of the Vagus Nerves for Peptic Ulcer, *Gastroenterology* **8** 36-51 [Jan] 1947) in the postoperative period. Their routine use might lower postoperative difficulties. Such drugs might also produce enough acid and motor reaction so as to delay both healing and the postoperative local "take-over" of the denervated stomach which, at the fourth to sixth month, is usually correlated with the disappearance of side-effects.

Their importance is difficult to assess, but it has been our practice to "clean" the esophagus through the area of dissection.

The diaphragm is then closed, leaving a hiatus that is snug but not tight, the mediastinal pleura is partially closed, and the chest is closed in layers without drainage. It has been our practice to aspirate the small quantity of occluded air from the chest with a catheter as the chest is closed. We have not used drainage in these cases and have had to resort to thoracentesis in only 3 cases.

Approximately 85 per cent of the patients in this series have been operated on by this method. One patient had an abdominal vagotomy with simultaneous posterior gastroenterostomy, 1 patient with pyloric obstruction had a preliminary posterior gastroenterostomy followed at a second stage by thoracic resection of the vagus nerves, both patients being treated in this fashion for purposes of special study. A few patients have had a supradiaphragmatic resection with no effort made to trace the nerves downward to their point of decussation.

II. POSTOPERATIVE MANAGEMENT

The postoperative handling of these patients may be divided into three categories—the management of the chest, of the stomach and of the patient's over-all clinical and nutritional condition.

The prevention of pulmonary complications involves early ambulation, the use of blow bottles, encouraging the patient to cough and take deep breaths and moving the patient freely in the bed. A firm, but not tight, thoracic binder gives the patient some sense of support and may help him in coughing and deep breathing. If the temperature is not returning to normal by the third day, a roentgenogram is taken, and if any significant amount of collapse persists bronchoscopy may be performed.

The postoperative management of the stomach is, of course, of the greatest importance. It is our impression that the early postoperative course of these patients, and possibly the late postoperative course, are more profoundly affected by the details of postoperative management of the stomach than by any other single factor. The dietary regimen should be essentially similar to that following a subtotal gastrectomy. The patient should be given only small amounts of fluid (less than 1 ounce [300 cc] an hour) for three to four days. The diet should then be started up cautiously, the stomach should be aspirated daily, and the diet should be "set back" if significant residue forms. Small amounts of solid food are far preferable to liquids.

It has been our practice to leave the Levine tube in place on suction for forty-eight hours in most cases. In occasional patients who have symptoms referable to the respiratory tract or a sensitive naso-

pharyngeal mucosa we have removed it earlier than this. In 1 patient with advanced bronchiectasis, in whom the tube was removed early in the hope of improving bronchial evacuation by cough, acute dilatation of the stomach occurred and doubtless would have been prevented had the tube been left in longer. This was the only frank acute dilatation of the stomach that we have had.

The patient should never be discharged from the hospital prior to the twelfth day. In several instances in which patients were discharged prior to the twelfth day they returned with troublesome symptoms which doubtless could have been prevented by longer hospitalization and more gradual dietary increase.

If the patient is kept in the hospital from twelve to fourteen days he becomes more familiar with his dietary limitations and has a smoother postoperative course. It should be emphasized that diarrhea in these patients is definitely associated with gastric distention and that the prevention of the latter is an important feature in controlling diarrhea. It, therefore, becomes evident that controlling the diarrhea is, in part, a problem in control of the patient's diet.

At the time the patient is discharged, he is given a sheet of instructions which include directions which he should follow in case of difficulty with diarrhea or fulness. The use of hot strong tea three times a day with or without the addition of camphorated tincture of opium is a useful adjunct in the treatment of diarrhea. It has been much more effective than some of the more complicated pharmacologic preparations. If the patient has "bouts" of fulness—which may often be accompanied by diarrhea—he is advised to stop eating completely for twelve hours and then to start eating small amounts of solid food. It has been a common experience in these patients that solid foods are tolerated better than liquid food. This seems at first glance to be a contradiction. On the other hand, one is not dealing with cicatrical pyloric stenosis in most of these cases, and when the pylorus opens it opens to a satisfactory extent. The difficulty is simply that the peristaltic action of the stomach is ineffectual in propelling the material through the pylorus. It is apparently the case that gastric peristalsis handles a bolus of solid food better than liquid after resection of the vagus nerves. Patients have stated repeatedly that small amounts of solid feeding are better tolerated by them than liquids. Liquids give them the "full" feeling, while solids do not. This fact may account for the peculiar contradiction often noticed that patients are nutritionally well and not complaining of symptoms despite large amounts of barium residual on a test meal. The use of solid foods after the fourth postoperative day has been found helpful in the early postoperative period, possibly for these same reasons.*

III HOSPITAL MORBIDITY AND MORTALITY

The hospital morbidity from this operation may be considered as falling into two categories (1) prolonged hospitalization due to difficulty in gastric emptying or other factors related to the gastrointestinal tract and (2) those postoperative complications including atelectasis, fluid, or other disorders of the chest directly attributable to the operation.

In general, the importance of both these complications together may be judged by the length of the hospital stay. If complications pertaining either to the chest or to the stomach occurred which did not prolong the patient's stay beyond fourteen days, they cannot be adjudged a major difficulty. If, on the other hand, the patient's stay in the hospital was unduly prolonged due to factors arising from either cause such factors must then be considered to be a major complication.

In the 74 cases under consideration, 11 patients had to stay in the hospital longer than fourteen days. Only 3 of these patients remained in the hospital twenty days or longer, and the longest stay was twenty-nine days. One patient, originally discharged from the hospital on the twelfth day, had to be readmitted within a week because of disorders of emptying which passed off with further hospital supervision.

Examination of the records of the patients who remained in the hospital more than fourteen days indicates that approximately two thirds of them were slow in being discharged because of time required to get them stabilized on a satisfactory diet. Only a few remained because of difficulties attributable to the chest. There is 1 patient in whom multiple chest taps had to be carried out because of collection of sero-sanguineous fluid the origin of which was undoubtedly traceable to poor hemostasis at operation. One patient had a phlebothrombosis requiring ligation of a vein. A bleeding episode fourteen days after operation (discussed in a later paragraph) necessitated a hospital stay longer than usual to be sure that the ulcer was healing satisfactorily before discharge. One patient remained in the hospital twenty-one days with vomiting, and the situation was complicated by the repair of a hiatus hernia, yet roentgen studies did not show mordant obstruction of the pylorus.

The incidence of pulmonary complications of a major sort has been low. The best single index of the presence of such complications may be found in the postoperative elevation of temperature. In this group of 74 patients there were 7 who had elevations of temperature to 103 F. or higher during the first few postoperative days. In all instances these elevations were due to atelectasis with attendant pneumonitis, none of the patients had wound sepsis or empyema. Three patients were subjected to bronchoscopy because of the presence of bronchial mucus of a tenacious sort which the patients were unable to expectorate. Whenever it was used, bronchoscopy was effective in controlling these symptoms. In the past year virtually all the patients have received

prophylactic treatment with penicillin postoperatively, discontinued on the fourth or fifth day if the temperature remained normal or if the temperature had returned to normal by that time. It is conceivable that this use of penicillin tends to mask some of the pulmonary complications which otherwise might produce a febrile course. In no patient has an intrathoracic complication of any lasting significance developed. Three cases of pneumothorax requiring repeated taps for two or three days have occurred, presumably due to a small alveolar leak where adherent lung has been freed.

If care is taken in dietary management, the prolongation of hospitalization due to poor emptying of the stomach need constitute only a minor problem. As a cause for excessive hospitalization, it has been unimportant in this series (7 cases out of 74). One patient, mentioned earlier, had a true acute dilatation of the stomach with falling chloride level and rising levels of nonprotein nitrogen. Treatment by resumption of gastric suction sufficed to reestablish satisfactory emptying. In another case, considered a borderline case of pyloric obstruction, the patient was advised preoperatively of the possible necessity for a second stage to the procedure, was not able to establish a satisfactory diet and had a posterior gastroenterostomy carried out before discharge. Other patients with partial obstruction have been treated by subtotal gastrectomy rather than by resection of the vagus nerves, and until more adequate follow-up is available on the patients with gastrojejunal stomas treated by resection of the vagus nerves that will be the future policy.

Postoperative bleeding presumably of ulcer origin has occurred within two weeks of operation in 2 patients who were operated on because of previous hemorrhage, quiescent at the time of operation. The cause of bleeding in the early postoperative period following resection of the vagus nerves in patients with bleeding ulcers may stem from various sources. It is conceivable that the relaxed smooth muscle of the intestinal wall which ensues after this operation permits an increased blood supply which might well reflect itself in bleeding. It is also to be emphasized that the healing of an ulcer after resection of the vagus nerves takes a definite period of time and that if a vessel should happen to be transiently opened during this period of healing, bleeding might ensue, as it might in the healing of any other open wound. The hospital mortality in resection of the vagus nerves for ulcer has been, in our experience to date, zero. Among the early cases a patient who was suffering from diffuse gastric atrophy, rather than ulcer, was operated on and succumbed. This case has been mentioned in a previous publication.^{1a} One patient died about nine months postoperatively of a cerebral vascular accident. Necropsy showed the ulcer to be satisfactorily healed. This case has likewise been previously reported and discussed in some detail^{1b} and does not constitute a postoperative hospital mortality.

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fulness as have the series of patients with duodenal ulcer. This again has dissuaded us from performing many gastroenterostomies. As a treatment for frank obstruction it is effective, as a means of avoiding gastrointestinal side effects it is ineffective.

V SUMMARY

The operative technic, postoperative management and hospital morbidity and mortality in a series of 74 patients with ulcer treated by resection of the vagus nerves have been reported. The thoracic approach has been used in 97 per cent of the cases.

Gastroenterostomy has been necessary postoperatively to relieve symptoms of obstruction in 2 cases—3 per cent of the series. In 2 other cases with frank cicatrical obstruction, primary gastroenterostomy was performed either before or with the resection of the vagus nerves.

It is hoped by the infrequency of gastroenterostomy to maintain this clinical experience in a state which will permit us, some years hence, to draw definitive conclusions about the value of resection of the vagus nerves. These conclusions will be difficult to draw if the operation is confused by the routine performance of posterior gastroenterostomy or other local procedures on the stomach which, in themselves, affect the natural course of peptic ulceration.

CLINICAL EVALUATION OF COMPLICATIONS OBSERVED AFTER TRANSTHORACIC VAGOTOMY

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THE CENTRAL Surgical Association's invitation to participate in this symposium on vagotomy as a method of treating peptic ulcer is welcome. Dr Dragstedt and his associates¹ have revived interest in the clinical and physiologic effects of vagotomy and have made observations that clarify many aspects of the problem of peptic ulcer. Our studies were encouraged by him. Preliminary impressions of clinical effects and summaries of roentgenologic, physiologic, and chemical studies have been presented.² Detailed reports will be published by

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From the Departments of Surgery, Roentgenology, Biochemistry and Medicine of Duke University School of Medicine

1 Dragstedt, L R, and Owens, F M Supra-Diaphragmatic Section of the Vagus Nerves in Treatment of Duodenal Ulcer, Proc Soc Exper Biol & Med 53 152-154, 1943 Dragstedt, L R, Palmer, W L, Schifer, P W, and Hodges, P C Supra-Diaphragmatic Section of the Vagus Nerves in the Treatment of Duodenal and Gastric Ulcers, Gastroenterology 3 450-462, 1944 Dragstedt, L R, and Schifer, P W Removal of the Vagus Innervation of the Stomach in Gastro-duodenal Ulcer, Surgery 17 742-749, 1945 Dragstedt, L R Vagotomy for Gastrroduodenal Ulcer, Ann Surg 122 973-989, 1945 Thornton, T G, Jr Storer, L H, and Dragstedt, L R Supradiaphragmatic Section of the Vagus Nerves Effect on Gastric Secretion and Motility in Patients with Peptic Ulcer, J A M A 130 764-771 (March 23) 1946

2 (a) Grimson, K S, Taylor, H M, Trent, J C, Wilson, D A, and Hill, H C The Effect of Transthoracic Vagotomy upon the Functions of the Stomach and upon the Early Clinical Course of Patients with Peptic Ulcer, South M J 39 460-472, 1946 (b) Russin, J M, Grimson, K S, and Smith, R C The Effect of Transthoracic Vagotomy upon the Clinical Course of Patients with Peptic Ulcer, Gastroenterology 7 599-606, 1946 (c) Smith, R C, Russin, J M and Baylin, G J The Effect of Transthoracic Vagus Resection upon Patients with Peptic Ulcer, South M J 40 1-10, 1947 (d) Grimson, K S, Baylin, G J, Taylor, H M, Hesser, F H, and Rundles, R W Transthoracic Vagotomy The Effects in Fifty-Seven Patients with Peptic Ulcer and the Clinical Limitations, J A M A 134 925-932 (July 12) 1947

individuals of the group, and the subject for this symposium will be only a brief clinical summary. No attempt will be made to review the literature or the recent excellent studies by Moore and his associates,³ Machella, Hodges and Lorber,⁴ and others.

Fifty-seven patients with refractory or frequently recurring peptic ulcer were treated by transthoracic vagotomy or transthoracic vagotomy and gastroenterostomy from July 1944 through September 1946. The transthoracic approach has been employed to minimize the chance of incomplete operation or of regeneration. The result in each patient has been determined by questionnaires, office visits and, with one exception, reexamination in the hospital. There was 1 death seventeen days after combined vagotomy and gastroenterostomy due to rupture of the stomach after an acute gastric dilatation and later a terminal massive hemorrhage from a duodenal ulcer.

Twenty-one of the remaining 56 patients are completely satisfied with the results of operation, 27 almost completely satisfied, 7 only partially satisfied and 1 dissatisfied because of an exacerbation of a preexisting gastrointestinal disturbance with vomiting and diarrhea.^{4a} The major causes of complete or almost complete satisfaction have been relief from pain, vomiting or hemorrhage and ability to eat a less restricted diet. Fifty patients have gained weight, with 21 regaining a weight equivalent to their greatest weight at any time before vagotomy. Nevertheless, serious difficulties have occurred in a few patients and moderately troublesome symptoms have developed in others.

The greatest difficulty has been occurrence of obstruction at the outlet of the stomach with retention of gastric content and dilatation. Obstruction may be caused by scar tissue but more frequently may be a result of abnormal function of the outlet of the stomach after removal of vagal control. Distention, accumulation of fluid and gas and loss of normal peristaltic pattern after vagotomy frequently make stomachs appear "tonic" during fluoroscopy. Intragastric pressures, however, as judged by balloon studies made after a twelve hour fast, have been increased by a few centimeters of water both immediately after vagotomy and one to two and one-half years later. Obstruction and retention have necessitated secondary gastroenterostomy in 5 patients, eleven to one hundred and five days after transthoracic vagotomy. Two others

³ Moore F D, Chapman, W P, Schulz M D, and Jones C V. Trans-diaphragmatic Resection of the Vagus Nerves for Peptic Ulcer, New England J Med 234:241-251, 1946. Resection of the Vagus Nerves in Peptic Ulcer Physiologic Effects and Clinical Results, J A M A 133:741-749 (March 15) 1947.

⁴ Machella T E, Hodges, H H, and Lorber, S H. The Restoration of Gastric Motility by Urethane of B-Methyl Choline After Section of the Vagus Nerves for Peptic Ulcer, Gastroenterology 8:36-51 1947.

^{4a} This patient died two years after vagotomy.

are now having serious symptoms from gastric retention but are being treated with partial success by parasympatheticomimetic drugs.

Since Dragstedt has now adopted subdiaphragmatic vagotomy and frequently combines it with gastroenterostomy and others are routinely combining vagotomy with subtotal gastric resection or gastroenterostomy, and since the relative merits of the combinations are discussed in the symposium this report will describe separately results in 36 patients treated by transthoracic vagotomy alone and in 20 patients with vagotomy and subtotal resection or gastroenterostomy.

TRANSTHORACIC VAGOTOMY WITHOUT GASTROENTEROSTOMY

Thirty-two of the 36 patients with vagotomy alone had duodenal ulcer and 4 gastric ulcer. Nine of the 32 patients are completely satisfied with results of operation, 22 almost completely satisfied and 5 only partially satisfied. Complications and causes of partial satisfaction varied.

Vomiting occurred occasionally during the first several months after vagotomy but did not persist. A single episode of hematemesis occurred in 2 patients seventeen and thirty-seven days after operation. With the possible exception of 1 patient who stated that he had had tarry stools there has been no further recurrence of bleeding. Mild pain similar to that formerly produced by ulcer occurred for several months in 1 patient and for twenty months but only after bouts of drinking in another. Episodes of moderately severe pain recurred in a third patient two months after operation and continued intermittently for twelve months, at which time an ulcer crater was demonstrated in the duodenum. Unexplained serious episodes of colicky abdominal pain occurred in this patient and in 2 others.

Twenty-eight of the 36 patients described a sensation of fullness after eating during the first three months after vagotomy, and this persisted in 11. Eighteen patients experienced foul eructations during the first three months. These were usually described as having a sulfurous odor as that of rotten eggs. Foul eructations have persisted in 10. Moderate swelling or distention of the abdomen was described during the first three months by 20 patients, and this persisted in 9. Moderately severe colicky abdominal pain described as "gas pains" occurred during the first three months in 7 patients and persisted in 5. Mild or occasional "lower bowel cramps" occurred in 16 patients and persisted in 8.

Before vagotomy there was a tendency toward constipation in most patients, and afterward either a normal bowel habit or a tendency toward soft and frequent stools. Of the 36 patients without gastroenterostomy, 20 had normal bowel habits after vagotomy, 4 moderate constipation, 11 a continuous or periodic looseness of stools and 1 a serious diarrhea.

TRANSTHORACIC VAGOTOMY WITH GASTROENTEROSTOMY

Of the 21 patients who had gastroenterostomy before, at the time of, or after vagotomy, 6 had marginal ulcers occurring after subtotal gastric resection, 3 marginal ulcers after gastroenterostomy, 2 gastroenterostomy just before vagotomy, 5 gastroenterostomy at the time of vagotomy and 5 gastroenterostomy after vagotomy. Since there was 1 operative mortality in this group, the number of patients followed is 20. Gastroenterostomies performed at the time of or after vagotomy often functioned poorly for many days or weeks.

Twelve of the 20 patients with vagotomy and gastroenterostomy are completely satisfied, 5 almost completely satisfied, 2 partially satisfied, and 1 dissatisfied. Complications and causes of partial satisfaction or dissatisfaction have varied.

Vomiting occurred infrequently during the first months after vagotomy and persisted only in 1 patient who had diarrhea and vomiting before operation. Hematemesis or tarry stools have not occurred. Mild pain similar to that formerly produced by ulcer recurred in 1 patient now observed twenty-one months. Pain followed bouts of drinking. Unexplained serious episodes of colicky abdominal pain occurred in 3 patients. One of them had had a stoma ulcer and had a nonfunctioning gastroenterostomy three months after vagotomy, a poorly functioning stoma with star-shaped mucosal folds resembling a healing ulcer at thirteen months and a better functioning stoma with less evidence of mucosal defect at twenty-six months, when the episode of colicky abdominal pain occurred.

Twelve of the 20 patients with gastroenterostomy described a sensation of fulness after eating during the first three months after vagotomy, and this persisted in 6. Eight patients experienced foul eructations during the first three months, and these persisted in 5. Moderate swelling or distention of the abdomen was described during the first three months by 7 patients, and this persisted in 5. Moderately severe colicky abdominal pain or "gas pains" occurred during the first three months in 6 and has persisted in 4. Mild or occasional episodes of "lower bowel cramps" occurred in 9 patients and persisted in 4.

The bowel habit of these 20 patients with gastroenterostomy was normal after vagotomy in 13. There were moderate constipation in 2 patients, continuous or periodic looseness of the stools in 2 and a serious diarrhea in 3.

COMMENT

The detailed physiologic, roentgenologic and chemical studies made on these patients have not been abstracted, since they are summarized in another publication^{2d}. Also beneficial effects of vagotomy have not been developed, since they are generally recognized and since most patients are well satisfied with results of operation. With 1 exception ulcers have healed or become quiescent.

EFFECT OF VAGOTOMY ON DEVELOPMENT OF THE MANN-WILLIAMSON ULCER IN THE DOG

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RECENT reports¹ showing the beneficial effect of vagotomy on peptic ulcer have been the stimulus for the experimental work herein reported. This investigation was conducted to determine (1) the effect of preliminary vagotomy on the development of the jejunal ulcer in the dogs on which the Mann-Williamson operation was done and (2) the effect on formation of ulcer when the vagotomy was performed after the Mann-Williamson operation.

Exalto² was the first investigator to report the incidence of jejunal ulcer in the dog following gastrojejunostomy with drainage of the duodenal contents into the colon. In his conclusions, valid to this day, he attributed the jejunal ulcer to the action of acid gastric juice on the intestinal mucosa.

Mann and Williamson³ performed an end to end gastrojejunostomy, draining the duodenal contents into the terminal part of the ileum approximately 25 cm from the ileocecal juncture. These investigators observed a large number of dogs and made a thorough study of the origin and evolution of the resultant lesions. The characteristics of the jejunal ulcers produced by diverting the duodenal secretions to the terminal part of the ileum have been outlined by them as follows:

1 Peptic ulcer develops in almost 100 per cent of dogs operated on.

2 The time of ulcer formation varies, perforation may occur in ten days or the ulcer may not start to develop for three months.

3 Although the animals lose weight rapidly and progressively, the change in physical condition does not appear to be a primary factor in the development of the ulcer.

4 Operative trauma is not a factor in ulcer formation.

5 Impairment of blood supply is not a factor in ulcer development.

6 The ulcer is always found in the intestinal mucosa, distal to the anastomotic suture line (within 1 cm), lateral and posterior to the central axis of the intestine.

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Read at the fourth annual meeting of the Central Surgical Association, Chicago,
Feb 20, 1947

1 Dragstedt, L R Ann Surg 122 973, 1945

2 Exalto, J Mitt a d Grenzgeb d Med u Chir 23 13, 1911

3 Mann, F C, and Williamson, C S Ann Surg 77 409, 1923

within one week after the operation was found to be pneumonia, volvulus, herniation of abdominal viscera, leakage at the suture line and operative shock. These animals were not used in evaluating the results of the experiments, since it is obvious that these animals had succumbed to the immediate effects of the operative procedures and the results could serve no statistical purpose.

A Control Series—Mann-Williamson Operation Only—The first or control series consisted of 15 animals subjected to the Mann-Williamson operation for internal duodenal drainage performed as follows:

With the dog under anesthesia with morphine and with pentobarbital sodium given intraperitoneally, the skin of the dog was aseptically prepared and a midline incision made in the upper part of the abdomen. The duodenum was transected at its pyloric juncture and the distal stump inverted. The jejunum was transected slightly distal to the duodenal-jejunal flexure at the ligament of Treitz. The distal limb of the transected jejunum was anastomosed end to end to the pylorus and the proximal limb anastomosed end to side to the terminal ileum approximately 25 cm from the ileocecal juncture.

In this control series A, 9 animals survived the Mann-Williamson operation. The experimental data herein analyzed are derived only from this surviving group.

B Vagotomy Followed by the Mann-Williamson Operation—In the second experimental group or series B, vagotomy was first performed as follows:

With the animal under anesthesia with morphine and with pentobarbital sodium administered intraperitoneally, an incision was made in the sixth intercostal space of the left side of the thorax, the intercostal musculature incised and retracted, exposing the parietal pleura. Under positive pressure, the pleural cavity was then opened and controlled respiration maintained throughout the operation until the thoracic cavity was closed. After the left lung had been retracted cephalad and medially, the mediastinal pleura investing the esophagus was incised, thus mobilizing the esophagus and facilitating its delivery into the operative field. The right and left vagus nerves were then identified coursing caudad on each side of the esophagus and isolated by blunt dissection, and a segment of nerve trunk 2 cm long was removed from each nerve, due care being exercised to extirpate all interlacing vagal fibers coursing from side to side around the periphery of the esophagus. The chest was then closed with interrupted linen sutures.

After a recovery period of approximately two weeks, the Mann-Williamson operation as previously described was performed on those animals which survived the preliminary vagotomy. Twenty animals were operated on in this series, but only 5 survived both the preliminary vagotomy and the subsequent Mann-Williamson operation. Data only from the surviving groups are analyzed. The unduly high mortality rate among the animals in this series was partially due to an epidemic of disease of the upper respiratory tract which was prevalent at the time.

B Vagotomy Followed by the Mann-Williamson Operation — In this series, the vagotomy was performed, and after an interval of two weeks to allow for recovery the Mann-Williamson operation was performed. At the second operation, pronounced atonic dilatation of the stomach and intestines was observed in all animals. The distention of the stomach in most instances was marked, the volume of the stomach had increased up to 800 cc. Food residue was found in the stomachs of all dogs in this series despite the withholding of food for twenty-four hours previous to operation. Vagotomy resulted in hypotonicity, hypomotility and dilatation of the gastrointestinal tract which was still evident two weeks after vagotomy.

Of the 5 animals in this series which survived the effects of both operations, 4 succumbed to the effects of perforated jejunal ulcer, the fifth dog (no 38) at necropsy was found to have a jejunal ulcer which

TABLE 1—*Control Series A Mann-Williamson Operation Only*

Dog No	Weight, Pounds	Date of Operation	Date of Death	Survival Time, Weeks	Loss of Weight, Pounds	Cause of Death and Comment
3	20	8/16/46	5/31/46	10	10	Perforated jejunal ulcer
4	28	4/5/46	6/22/46	11	7	Perforated jejunal ulcer
5	20	4/19/46	6/10/46	9	7	Perforated jejunal ulcer
6	29	4/26/46	5/24/46	4	9	Perforated jejunal ulcer
7	19	5/3/46	5/20/46	3	8	Inanition, no ulcer present
8	17	5/10/46	7/17/46	9	9	Perforated jejunal ulcer
10	16	5/24/46	6/23/46	4	6	Inanition, no ulcer present
10	20	7/12/46	8/8/46	3	9	Inanition no ulcer present
39	29	10/5/46	10/80/46	4	12	Jejunal ulcer, not perforated, severe hemorrhage

Number of dogs 9
 Number of dogs with ulcer 6
 Incidence of ulcer 67%,
 but the other 33 per cent (3 cases) died so early following operation that insufficient time had probably elapsed for formation of ulcer

was not perforated. The vagotomy, including extirpation of all interlacing fibers, was found complete in all postmortem examinations. No evidence of regeneration of the sectioned vagi was noted. The site of the jejunal ulcer which developed in all animals in this series was lateral and posterior to the central axis of the bowel, approximately 4 to 6 mm distal to the anastomotic suture line. Vagotomy failed to protect against development of the Mann-Williamson ulcer in the dogs in this series.

The results for this series, as noted in table 2, constitute an incidence of ulcer of 100 per cent. The survival time of the 5 animals ranged from two weeks to six weeks, or an average of three and one-half weeks from the date of the second (Mann-Williamson) operation. The loss in weight for this group averaged approximately 35 per cent of the preoperative weight and was fairly constant in all animals.

C Mann-Williamson Operation Followed by Vagotomy — In this series, the Mann-Williamson operation was performed first. After an

after vagotomy by patients with ulcer that I am inclined to discount completely the significance of these experiments as related to clinical experience. In spite of the fact that the Mann-Williamson ulcer might be considered to resemble the peptic ulcer in man, the discrepancy in results following vagotomy in man as compared to the results in the experiments with animals leads me to the conclusion that the pathogenesis of ulcer following the Mann-Williamson operation in dogs is different from that of ulcer in man.

The role of acid in the production of ulcer in man, and particularly in its incidence, appears to be too definite to be disputed, at least in my opinion. It is a well known fact, as shown by numerous investigators, that vagotomy in animals produces a definite decrease in the amount of acid and in the total volume of gastric secretion in the dog. How can the failure of protection against formation of ulcer in the

TABLE 3—*Series C Mann-Williamson Operation Followed by Vagotomy*

Dog No	Weight Pounds	Date of Operation	Date of Death	Survival Time After Vagotomy, Days	Loss in Weight, Pounds	Cause of Death and Comment
9 18	30 13	5/17/46 6/14/46	8/12/46 8/12/46	12 4	18 5	Inanition—erosion of jejunum No ulcer, inanition, stomach dilated
17 24 25 29	22 21 26 21	7/19/46 8/ 9/46 8/ 9/46 9/ 4/46	8/29/46 9/ 6/46 9/ 9/46 10/ 3/46	15 8 11 1	10 9 14 7	Large perforated jejunum ulcer Large perforated jejunum ulcer Perforated ulcer of jejunum No ulcer, stomach markedly dilated
30	18	8/30/46	10/ 5/46	8	4	Perforated jejunum ulcer
Number of dogs						7
Number of dogs with ulcer						5
Incidence of ulcer						71%

dogs on which the Mann-Williamson operation had been done, as noted in these experiments, be correlated with the two supposed facts just mentioned? One is led to the obvious conclusion that the excess acid is not the sole cause of ulcer. There must be another factor of great importance. This factor might be contained in bile, pancreatic or duodenal secretion, or in all three, since in the Mann-Williamson operation all three secretions are diverted from their usual location just distal to the stomach, where experimental ulcers are found, it may be that some chemical in one or more of these secretions serves to protect against their formation. However, there is ample evidence to prove that none of these three possible factors is sufficiently potent alone to produce ulcers, since the elimination of bile from the intestinal tract (by obstruction of the common duct) or of duodenal secretion and pancreatic secretion (by resection of the duodenum in carcinoma of the head of the pancreas) does not produce ulcers in a significant number of patients.

The benefit of feeding extracts of duodenum and of the upper part of the jejunum to patients with ulcer as reported by Ivy⁵ and his associates offers proof that the correction of one factor (exclusive of the acid factor) may relieve ulcer in man. On the other hand the good results following vagotomy in patients with ulcer may be ascribed to correction of the hyperacid factor unless one assumes that it also corrects a physiologic error in the secretions from the liver, pancreas or duodenum.

SUMMARY

In the 9 control animals (series A) in which only the Mann-Williamson operation was performed, ulcer developed in 6 animals constituting an incidence of 67 per cent. A further analysis of the results in the control series reveals that the 6 dogs in which ulcers developed survived an average of eight weeks from the date of operation and lost approximately 35 per cent of their preoperative body weight during this period. These data are contrasted with an average survival time of three weeks from the date of operation and an average loss in weight of 50 per cent of their preoperative body weight in those animals in which ulcers did not develop.

Mann and Williamson in a large series of animals noted formation of ulcers in 98 per cent of their experimental animals, the time of formation varying from ten days to three months from the date of operation. All dogs which survived four weeks or longer after the Mann-Williamson operation only, succumbed to perforated ulcer. Obviously, in the series herein reported it can be assumed that the 3 dogs in which ulcer did not develop might ultimately have had one had they survived longer and been better able to maintain their nutritional state.

In those experimental animals in which the preliminary vagotomy was followed in two weeks by the Mann-Williamson operation (series B) the incidence of ulcer in those animals which survived the effects of the second operation by two weeks or longer was 100 per cent. All died of perforated ulcer. This is a higher incidence of ulcer than in the control group. The average survival time for the animals in this series was three weeks, during which time the animals lost approximately 35 per cent of their preoperative body weight. The debilitating effects of the two operations combined with the irritating effects of gastric retention of food, occasioned by tonic dilatation hypomotility and hypotonicity following vagotomy might be construed as facilitating the earlier development of the ulcer in this series as contrasted with the time of development in the control series.

viving both operations, 4 succumbed to perforation of the ulcer, fifteen, eight, eleven and eight days, respectively, after vagotomy. A fifth dog died twelve days after vagotomy and at necropsy exhibited a slight erosion of the jejunum which might have represented a healing ulcer. The remaining 2 animals which did not show an ulcer at necropsy died one and four days following vagotomy, an interval of time too short to assume that vagotomy might have beneficially produced complete healing. It is probably more correct to assume that in these 2 animals the ulcer had not been present when the vagotomy was performed.

The incidence of development of ulcer for each series is set forth in table 4.

TABLE 4.—*Incidence of Development*

	Number of Dogs	Number of Dogs with Ulcer	Incidence of Ulcer, Percentage
Control series A, Mann Williamson operation only	9	6*	67
Vagotomy followed by Mann Williamson operation	5	5	100
Mann Williamson operation followed by vagotomy	7	5	71

* The other 8 dogs died so soon after operation that there may have been no opportunity for formation of ulcer.

CONCLUSION

Bilateral supradiaphragmatic section of the vagi failed to prevent the ulcer produced by the Mann-Williamson operation for internal duodenal drainage in the dog. Since I am convinced that vagotomy produces a definite benefit (at least temporarily) in patients with peptic ulcer, I conclude that the pathogenesis in the two types of ulcer is too different to allow any correlation of these experimental results with the clinical results of vagotomy in peptic ulcer. However, the results of these experiments do suggest that there is another factor besides the role of acid in formation of ulcer in man. Since bile and duodenal and pancreatic secretions are diverted from their normal location in the Mann-Williamson operation, this second factor could theoretically be contained in any of the three secretions mentioned.

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DENERVATION OF THE STOMACH

Historical Review

JOHN T. SMALL, M.D.
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'Now good digestion waits on appetite
And health on both!'

Macbeth—Act 3, Scene 4

STATISTICS show that the incidence of peptic ulcer has risen with the pace of modern living,¹ but also improved diagnosis has probably relabeled as peptic ulcer some of the gastric neuroses, dyspepsias and neuralgias of the stomach and visceral neuroses of the pre-Roentgen era.² The influence of the mind over digestion, however, was recognized by the ancients, and when the anatomists discovered that the tenth cranial nerve extended from brain to colon, the early observations seemed to have an anatomic basis.

The *Philosophical Transactions of the Royal Society of London*, first published in 1664, was in effect the first international organ for the dissemination of scientific information. One hundred and fifty years later, Benjamin Brodie published therein the first clearcut observations of the influence of the vagus nerves on the secretions of the stomach.³ He had sectioned both nerves in the necks of 3 dogs and later killed the dogs with arsenic. He observed, however, that the embarrassment of respiration was interfering with his results. His fourth experiment is worth reviewing:

Having made an incision in the abdomen of a dog immediately below the short ribs, I divided by means of a bistoury, the stomachic ropes formed by the nerves where they are situated on the esophagus immediately above the cardiac orifice of the stomach. The wound was closed by sutures. The respiration was

From the Surgical Service, Mayo Clinic, and under the direction of Dr. Waltman Walters

1 Wood, W. Q. The Treatment of Duodenal Ulcer, Edinburgh M. J. 52 433-450 (Dec) 1945

2 Allbutt, T. C. Visceral Neuroses, Being the Gulstonian Lectures on Neuralgia of the Stomach and Allied Disorders, Philadelphia, P. Blakiston, Son & Company, 1884

3 Brodie, B. C. Experiments and Observations on the Influence of the Nerves of the Eighth Pair on the Secretions of the Stomach, Phil. Tr., London 104 102-106, 1814

not in the least disturbed but was performed as frequently, and with as much ease, as under ordinary circumstances. The animal was afterwards inoculated in the thigh with the white oxide of arsenic, and he died in a few hours after the application of the poison with the ordinary symptoms except that there was no fluid evacuation from the stomach or intestines.

On dissection, the mucous membrane of the stomach and intestine was found inflamed. There was no watery or mucous fluid in the stomach or small intestine. There was a small quantity of mucus in the colon.

The result of this being the same as that of the former exp'ts we may conclude that the suppression of the secretion in all of them was to be attributed solely to the division of the nerves, and all of the facts which have been stated sufficiently demonstrate that the secretions of the stomach are very much under the control of the nervous system.

This early experimenter gave credit to previous unnamed workers. He also pointed out the limitations of his method but forecast its eventual solution.

It has been attempted by former physiologists to determine how far the nerves are necessary to secretion. The only method which can be devised of ascertaining by direct experiment whether the nerves are really necessary to secretion is that of dividing the nervous branches by which the glands are supplied, but this with respect to the greater number of glands is an experiment impossible to perform, and with respect to others cannot be executed without so much disturbance and injury to the other parts as must render it extremely difficult to arrive at positive results. Perhaps in future investigations, some circumstance may arise which will enable us to determine more satisfactorily this important physiological question.

Since the fundamental work of Brodie the influence of the gastric nerves has been investigated along the three principal lines of secretion, motility and conduction of sensation. Many animal species have been employed in the laboratory and many pathologic states of human beings have been treated by denervation of the stomach. The extent of the operation has varied in the hands of different workers from simple division of nerves to complete excision of all branches in a large region. The existence of so many variables calls for caution in the evaluation of such procedures and no doubt accounts for the bizarre and often conflicting results which are reported. At the present time many surgeons are employing interruption of the gastric nerve supply in an attempt to treat the primary disease or secondary effects of peptic ulcer. This is not a new concept in treatment but has been widely investigated and practiced in the past. The purpose of the present study is to acquaint the reader with these past and present studies which are relevant to the understanding and further evaluation of this procedure.

ANATOMY

The vagi lose their identity at the level of the roots of the lungs. Behind the roots of the lungs, on both sides, lies the pulmonary plexus.

From this plexus the vagi incline anteromedially to break up into a variable number of branches which cross communicate on the esophagus to form the so-called esophageal plexus. At varying levels above the diaphragm the trunks reform and enter the abdomen via the esophageal hiatus. Each trunk contains elements of both vagi in addition to sympathetic fibers. These trunks are properly called the "gastric nerves" and are the structures which are sectioned when neurectomy is performed at the level of the lower part of the esophagus. Babkin⁴ has stated that mere morphology is no criterion of the mode of action of a nerve for action depends on the adrenergic or cholinergic properties at the nerve ending. One group of investigators concluded that the vagi contain only sympathetic fibers below the ganglion nodosum,⁵ whereas another stated that they are entirely parasympathetic in origin.⁶ White and Smithwick⁷ have stated rather bleakly that neurosurgical methods have failed to relieve such clinical conditions as hyperacidity and pylorospasm since the essential mechanism that controls digestion lies in the intrinsic plexuses of the gastrointestinal tract. It is well known that preganglionic fibers of the vagus and sympathetic nerves have extraordinary powers of regeneration and Cannon⁸ has reported cardioinhibitor fibers rejoining the heart even after the intrathoracic portion of the vagus nerve has been transplanted to a new position outside the ribs.

Latarjet and Wertheimer,⁹ Mitchell¹⁰ and McCrea¹¹ have clarified the distribution of the extrinsic nerves of the stomach in man and

⁴ Babkin B. P. *Secretory Mechanism of the Digestive Glands*, New York, Paul I. Hoeber Inc. 1944

⁵ Kiss J. *The Relation Between Vagus and Sympathetic in Vertebrates*, *J Anat* **66** 153-156 (Jan) 1932

⁶ McSwiney, B. A. and Spurrell W. B. *The Gastric Fibres of the Vagus Nerve* *J Physiol* **77** 447-458 (March 15) 1933

⁷ White J. C. and Smithwick R. H. *The Autonomic Nervous System Anatomy, Physiology and Surgical Applications*, New York, The Macmillan Company 1947 pp 355-374

⁸ Cannon W. B. cited by White and Smithwick⁷

⁹ Latarjet, A. *Resection des nerfs de l'estomac Technique opératoire, Résultats cliniques*, Bull Acad de méd, Paris **87** 681-691 (June 20) 1922, *Note préliminaire sur l'innervation et l'enervation de l'estomac*, Lyon med **130** 166-167 (Feb 25) 1921

¹⁰ Latarjet, A., and Wertheimer, P. *Quelques résultats de l'enervation gastrique*, *Presse med* **2** 993-995 (Nov 28) 1923

¹¹ Mitchell, G. A. G. *Nerve-Supply of Gastro-Esophageal Junction*, *Brit J Surg* **26** 333-345 (Oct) 1938, *A Macroscopic Study of the Nerve Supply of the Stomach*, *J Anat* **75** 50-63 (Oct.) 1940

¹² McCrea, E. D. *The Abdominal Distribution of the Vagus*, *J Anat* **59** 18-40 (Oct) 1924, *The Nerves of the Stomach and Their Relation to Surgery*, *Brit J Surg* **13** 621-648 (April) 1926

other species, although this subject has been treated rather superficially in the modern textbooks of anatomy. All of these workers have shown that the gastric nerves do not reach the pylorus directly but end at the angle of the stomach. The pylorus is innervated by recurrent branches in the lesser omentum which are richly mixed with sympathetic fibers from the celiac plexus. Latarjet is responsible for the terms "nerves of the lesser curvature" and "nerves of the greater curvature" for the nerves which extend to the angle of the stomach. McCrea pointed out the large branch of the right gastric nerve, which invariably travels with the left gastric artery to the celiac plexus. Recently Bradley, Wilson, Walters and I reported our findings at necropsy in 111 cases on the distribution of the vagus nerves to the esophageal plexus and thence to the gastric nerves.¹³ This work revealed no significant variation related to age, sex or pathologic state and indicated that complete subdiaphragmatic section of the gastric nerves was possible in more than 90 per cent of cases. We emphasized the need for some standardization of terminology and suggested the term "gastric neurectomy" for total or partial resection of the gastric nerves, "gastric neuromy" for simple division and the use of "vagotomy" for unilateral or bilateral division of the distinct vagus nerves above the cardiopulmonary plexuses.

LABORATORY STUDIES

Many investigators have found that the anatomic distribution of gastric nerves in the rabbit, cat and dog, animals which often are used in study of gastric denervation, is remarkably similar to that in man. Pavlov¹⁴ and later Babkin¹⁵ showed that secretion of gastric juice was intermittent in the dog, whereas Carlson¹⁶ has found that in man it is continuous even during fasting and may even be increased during sleep. This does not indicate any fundamental difference between the activities of gastric glands of man and dogs but rather verifies the fact that it is impossible to eliminate psychic stimuli in the human subject. On the other hand comparison of results of gastric denervation must be made cautiously, since many workers have employed this procedure for the experimental production of peptic ulcer. A frequent error is to apply

13 Bradley, W F, Small, J T, Wilson, J W, and Walters, W Anatomic Considerations of Gastric Neurectomy, *J A M A* **133** 459-461 (Feb 15) 1947

14 Pavlov, I P The Work of the Digestive Glands, translated by W H Thompson, ed. 2, London, C Griffin & Company, 1910

15 Babkin, B P Die äussere Sekretion der Verdauungsdrüsen, Berlin, Julius Springer, 1914

16 Carlson, A J The Secretion of Gastric Juice in Health and Disease *Physiol Rev* **3** 1-40 (Jan) 1923

the findings in the lower animals to man without the necessary reservations

The stomach was long regarded as a mechanical mill for the mixing and grinding of food such as the gizzard in birds, until Reaumur (1683-1757) and Spallanzani (1729-1799) both showed that gastric juice could digest meat *in vitro*. This finding shifted attention to the chemical aspects of gastric function where perhaps unfortunately, it has remained. However complete absence of the gastric juice may exist without apparent difficulty in digestion and Best and Taylor have stated that the immediate factors responsible for the production of the various symptoms of gastric disease probably are always mechanical in nature.¹⁷ Ten years after Brodie's discovery of the influence of nerve supply on gastric secretion Prout showed that the acid content of gastric juice was hydrochloride. In the same year Beaumont began his work with Alexis St Martin.¹⁸ The production of free mineral acid during the living process is encountered but rarely, and Claude Bernard¹⁹ was among the first to investigate its origin in the mucosa of the stomach.

After Billroth and his school established gastrointestinal surgery on the heels of anesthesia and antisepsis a deeper understanding of the whole complicated story of digestion became necessary. Around the turn of the century Pavlov defined and demonstrated the phases of gastric secretion and his experimental work on dogs is the basis of present knowledge. The variations of the Heidenham and Pavlov pouches with and without nerve supply, gave information concerning the role of the gastric nerves in the control of sensation, secretion and motility and surgeons soon began to use this knowledge in the treatment of various afflictions of the stomach.

Although Brodie had proved experimentally that the gastric nerves exerted control over gastric secretion it remained for Pavlov and his followers to show that there were at least three phases to this phenomenon. It was ushered in by the cephalic phase, which in turn could be eliminated by sectioning these nerves. Alley²⁰ and Babkin later showed that stimulation of the vagus nerves caused secretion of a juice

17 Best, C H, and Taylor, N B. *The Physiological Basis of Medical Practice*, ed 3, Baltimore, Williams & Wilkins Company, 1943, p 717

18 Cannon, W B. *The Book of William Beaumont After One Hundred Years*, Bull New York Acad Med 9 568-584 (Oct) 1933

19 Bernard, C, *Cours de physiologie generale du Museum d'histoire naturelle de la vie commune aux animaux et aux vegetaux*, Paris, J-B Baillière & fils, 1878

20 Alley, A. *The Secretory Activity of the Gastric Mucosa in the Region of the Lesser Curvature*, Tr Roy Soc Canada 27 71, 1933

which was both high in pepsin and strongly acid and was largely secreted from the region of the lesser curvature, which is the usual site of gastric ulcer. Vineberg²¹ also indicated that the same nerves influenced the secretion of mucus from mucous neck cells and the gastric epithelium. He also found that mucus was capable of neutralizing acid and was useful in the treatment of ulcer. The influence of the sympathetic nerves has not been clarified but is apparently inhibitory to these functions. Variations in the pepsin and acid content of the gastric juice occur with the taking of different foods or the emotional state of the animal and strongly point to the role of the higher centers in modifying the reflexes. Even the sight or smell of food may excite the cephalic phase of secretion, and Babkin has shown that this phase may appear at the regular mealtime of laboratory animals although no external stimulus is present.

The location of autonomic areas in the higher centers has been extensively investigated. Goltz²² was able to induce sympathetic and parasympathetic effects in dogs which had been decorticated, and ample evidence indicates that there are no separate regions for sympathetic and parasympathetic outflow from the cortex of the brain. Cushing²³ was the first to record the frequent occurrence of duodenal ulcer in association with lesions of the midbrain, and the recent experimental work of Beattie,²⁴ Sheehan²⁵ and others has indicated discrete centers in the preoptic and anterior hypothalamic areas which control various autonomic functions.

Leubuscher and Schäfer²⁶ in 1894, Borutta²⁷ in 1896 and Herzen²⁸ in 1897 sectioned the vagus nerves in various experimental

21 Vineberg, A M. The Activation of Different Elements of the Gastric Secretion by Variation of Vagal Stimulation, Am J Physiol **96** 363-371 (Feb.) 1931

22 Goltz, F. Der Hund ohne Grosshirn. Siebente Abhandlung über die Verrichtungen des Grosshirns, Arch f d ges Physiol **51** 570-614 (March 26) 1892

23 Cushing, H. Papers Relating to the Pituitary Body, Hypothalamus and Parasympathetic Nervous System, Springfield, Ill., Charles C Thomas, Publisher, 1932, Peptic Ulcers and Interbrain (Balfour Lecture), Surg, Gynec & Obst **55** 1-34 (July) 1932

24 Beattie, J. The Relation of the Tuber Cinereum to Gastric and Cardiac Functions (A Preliminary Note), Canad. M A J **26** 278 (March) 1932

25 Sheehan, D. The Autonomic Nervous System, in Luck, J M. Annual Review of Physiology, Stanford University, Calif., Annual Reviews, Inc., 1941, vol 3, pp 399-448

26 Leubuscher and Schäfer, A. Über die Beziehungen des Nervus vagus zur Salzsäuresekretion der Magenschleimhaut, Zentralbl f inn Med **15** 761-767 (Aug 18) 1894

27 Borutta, H. Weitere Erfahrungen über die Beziehungen des N vagus zur Atmung und Verdauung, Arch f d ges Physiol **65** 26-40 (Oct. 31) 1896

28 Herzen, P. Les causes de mort apres la double vagotomie dans leur rapport avec les conditions de Survie, Paris, J-B Baillière & fils, 1898

animals and noted failure of digestion when this principal parasympathetic pathway was disturbed. The discovery of the roentgen rays greatly stimulated both clinical and experimental investigation of digestion in general and the stomach in particular. In 1929 Hartzell²⁹ gave an excellent review of the work of McCrea, Latajlet, McSwiney and Stopford and others when he reported his observations on dogs in which the vagi were cut above and below the diaphragm. He confirmed the abolishment of the cephalic phase of secretion, the loss of tone and the increased emptying time in the denervated stomach of the dog. In 1931 Vanzant³⁰ reexamined Hartzell's dogs and found that secretion and acidity had returned almost to normal despite the fact that the nerves were completely divided and showed no evidence of regeneration.

In 1925 Lum, Ivy and McCarthy³¹ pointed out that many of the variations in the results reported by different investigators up to that time might be explained by the fact that the branches of the vagus nerves had been sectioned at different levels and had produced various types of denervation. Koennecke³² and Meyer³³ in 1922 also exhaustively reviewed the subject and cautioned against drawing conclusions from the denervation of stomachs of healthy animals and comparing them to the effects on the ailing organ in man. Greggio³⁴ and Durante³⁵ in 1916, Beaver and Mann³⁶ in 1931, Beazell and Ivy³⁷ in 1936 and Lum³⁸ in 1941 were able to produce gastroduodenal ulceration in

29 Hartzell, J. B. The Effect of Section of the Vagus Nerves on Gastric Acidity, *Am J Physiol* **91** 161-171 (Dec) 1929

30 Vanzant, F. R. Late Effects of Section of the Vagus Nerves on Gastric Acidity, *Am J Physiol* **99** 375-378 (Jan) 1932

31 Lum, R. K. S., Ivy, A. C., and McCarthy, I. I. Contributions to the Physiology of Gastric Secretion I. Gastric Secretion by Local (Mechanical and Chemical) Stimulation, *Quart J Exper Physiol* **15** 13-53, 1925

32 Koennecke, W. Experimentelle Innervationsstörungen am Magen und Darm, *Ztschr f d ges exper Med* **28** 384-412 (March 23) 1922

33 Koennecke, W., and Meyer H. Rontgenuntersuchungen über den Einfluss von Vagus und Sympathicus auf Magen und Darm, *Mitt a d Grenzgeb d Med u Chir* **35** 297-323, 1922

34 Greggio, E. Des ulcères gastro-duodénaux, *Arch de med exper et d'anat path* **28** 533-590, 1916-1917

35 Durante, L. The Trophic Element in the Origin of Gastric Ulcer, *Surg, Gynec & Obst* **22** 399-406 (April) 1916

36 Beaver, M. G., and Mann, F. C. Production of Peptic Ulcer After Section of Gastric Nerve, *Ann Surg* **94** 1116-1118 (Dec) 1931

37 Beazell, J. M., and Ivy, A. C. Chronic Gastric Ulcer Following Bilateral Vagotomy in the Rabbit and the Dog, *Arch Path* **22** 213-219 (Aug) 1936

38 Lum, R. Peptic Ulcer and Diarrhea Following the Removal of the Prevertebral Ganglia in Dogs. The Antispasmodic Effects of Magnesium Sulfate Pentobarbital and Atropine Sulfate, *Surgery* **9** 538-553 (April) 1941

rabbit and dog by denervation. Knight,³⁹ Ferguson⁴⁰ and associates about 1934 found a condition in the cat and monkey which simulated cardiospasm in human beings after denervation was performed.⁴¹ Such variable results justify an attitude of caution concerning the use of this procedure as a therapeutic measure.

CLINICAL USE OF GASTRIC DENERVATION

Jaboulay¹⁻ in 1901 recorded the first deliberate denervation of the stomach in a human being for the purpose of relieving the lightning pains of tabes dorsalis. He reported good results from resection of the celiac ganglion, and his operation was based on the supposition that the afferent (sensory) fibers from the viscus led to this cell station (fig 1A).

Exner and Schwarzmann⁴³ in 1912 and later used the abdominal approach and divided only the anterior (left) gastric nerve (fig 1B). They also were interested in relieving lightning pains. They reported 20 cases with 1 death and good results in 50 per cent of cases. They noted atony of the stomach and pylorospasm and recommended simultaneous gastroenterostomy in order to avoid gastric retention and failure of digestion. Barron and Curtis⁴⁴ and more recently Weinstein⁴⁵ and associates have used this procedure in relief of complicated duodenal ulcer.

Bircher¹⁶ in 1920 and 1921 performed denervation in order to relieve gastric pains of varied causation. He interrupted the nerve

39 Knight, G C Relation of the Extrinsic Nerves to the Functional Activity of the Esophagus, *Brit. J. Surg.* **22** 155-168 (July) 1934 Knight, G C, and Adamson, W A D Achalasia of the Cardia, *Proc Roy Soc Med* **28** 891-897 (Jan 2) 1935

40 Ferguson, J H Effects of Vagotomy on the Gastric Functions of Monkeys, *Surg., Gynec. & Obst.* **62** 689-700 (April) 1936

41 Ochsner, A, and DeBakey, M Surgical Aspects of Carcinoma of the Esophagus Review of the Literature and Report of Four Cases, *J Thoracic Surg* **10** 401-445 (April) 1941

42 Jaboulay, M La chirurgie du sympathique abdominal et sacra, *Zentralbl f Chir* **1** 227-228 (Feb 23) 1901

43 Exner, A, and Schwarzmann, E Tabische Krisen, Ulcus ventriculi und Vagus, *Wien klin Wochenschr* **25** 1405-1406 (Sept 19) 1912, Gastrische Krisen und Vagotomie, *Mitt a d Grenzgeb d Med u Chir* **28** 15-52, 1914-1915

44 Barron, I E, and Curtis, G M Effect of Vagotomy on the Gastric Motor Mechanism in Man, *Arch Surg* **34** 1132-1158 (June) 1937

45 Weinstein, V A, Hollander, F, and Jemerin, E E Vagotomy in the Therapy of Peptic Ulcer, *Surg., Gynec. & Obst.* **79** 297-305 (Sept) 1944

46 Bircher, E Die Resektion von Aesten der N vagus zur Behandlung gastrischer Affektionen, *Schweiz med Wochenschr* **50** 519-528 (June) 1920, abstracted *Arch d mal de l'app digestif* **11** 135-137, 1921

supply of the lesser curvature by dissecting the omentum and stated that an advantage of this minor denervation was the lack of atony and the necessity for gastroenterostomy (fig 1C). There was a controversy in the literature between Bircher and others who favored more radical types of denervation.

Stierlin⁴⁷ and Steinthal⁴⁸ writing in 1920 both recommended a more radical operation than the one which Bircher used. In addition to denervation of the lesser curvature by removal of the omentum they

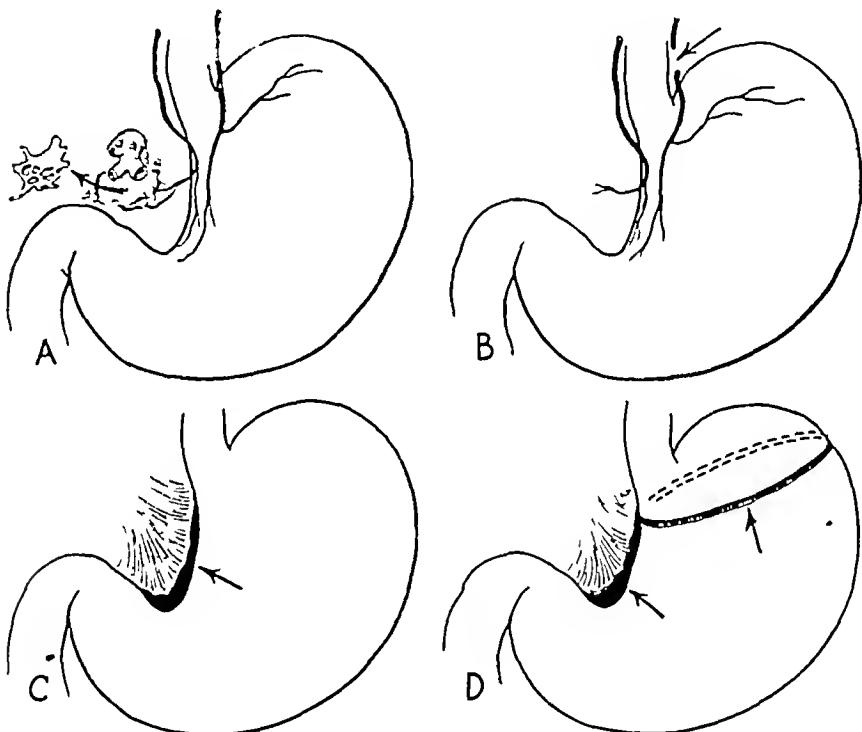


Fig 1.—A, Jaboulay in 1901 excised the celiac plexus (schematic representation); B, Exner in 1912 divided the left gastric nerve (schematic representation); C, Bircher in 1920 used denervation of the lesser curvature (schematic representation); D, Stierlin in 1920 performed denervation of lesser curvature and circumcision (schematic representation).

incised the serosa and muscle down to the submucosa completely around the stomach at the level indicated in figure 1D.

47 Stierlin, E. Ueber den Mageninnervation in ihrer Beziehung zur Atologie und Therapie des Ulcus, Deutsche Ztschr f Chir 152:358-392, 1920.

48 Steinthal, C. Die Ausschaltung des N. Sympathicus und N. vagus nach Stierlin bei Ulcus ventriculi, Zentralbl f Chir 47:1293-1294 (Oct) 1920.

Latarjet,⁹ Wertheimer,¹⁰ Pauchet and associates,¹¹ after carrying out exhaustive experiments and anatomic investigations, evolved an operation which was performed in a total of 59 reported cases. Most of these operations were for ulcer of stomach or duodenum. In all but eighteen gastroenterostomy was required in order to drain the atonic stomach, and most of these eighteen operations were for "vagotonics without demonstrable lesions." Latarjet reported 1 case in which the patient returned in one year because of carcinoma which had developed

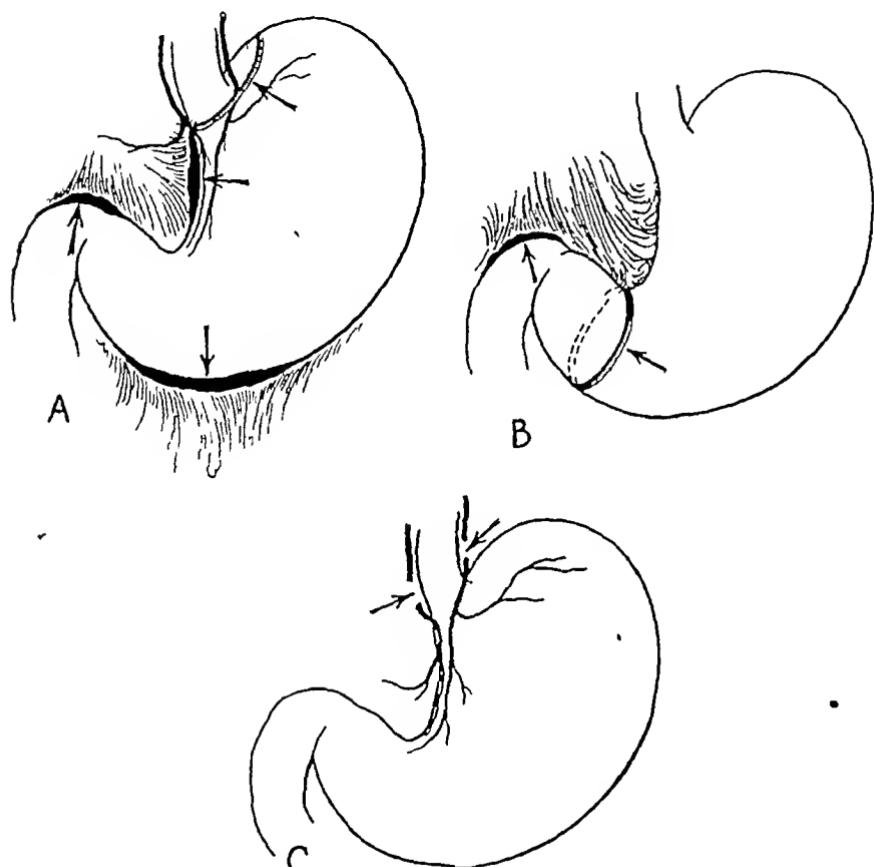


Fig 2.—*A*, Latarjet in 1921 performed denervation of greater and lesser curvatures and suprapyloric region and partial circumcision (schematic representation of denervation). *B*, Schiassi in 1925 performed denervation of suprapyloric region with circumcision (schematic representation of denervation). *C*, Picri and Tanferna in 1930 divided both gastric nerves (schematic representation).

without symptoms in the denervated stomach. The operation which this group used was designed to sever all the extrinsic nerves to stomach

⁹ D'Ormond, R de B. Neurectomy of the Stomach, in Pauchet, V Practical Surgery Illustrated, translated by F R B Atkinson London, Ernest Benn Ltd, 1925, vol 6, chap 3, pp 41-52

and pylorus and to leave intact the large branch of the right gastric nerve which accompanies the left gastric artery to the celiac plexus (fig 2A) McCrea⁵⁰ in 1924 stated that the Latarjet operation was the one of choice for complete denervation of the stomach, without interruption of vagal supply to other organs.

Schiassi⁵⁰ in 1925 reported the results of a slightly modified operation in 26 cases. He incised the entire circumference of the stomach down to the submucosa at a low level and also divided the pyloroduodenal nerves which come down in the lesser omentum (fig 2B). In 15 cases in which the operation was done for duodenal ulcer Schiassi was satisfied with his results. His work was published in American literature and he no doubt influenced such surgeons as C H Mayo,⁵¹ who began stripping the omentum from the lesser curvature and pylorus to divide the pyloric nerves in order to relieve the symptoms of duodenal ulcer.

Pieri and Tanferna⁵² in 1930 and Pieri⁵³ in 1932 divided both gastric nerves below the diaphragm (fig 2C). They reported 8 cases of duodenal ulcer in which this operation was used without gastroenterostomy. This is the same operation, although probably less extensive, which was revived by Dragstedt⁵⁴ in 1943. Its use is now being reported frequently, but the results are rather conflicting.⁵⁵

50 Schiassi, B. The Role of the Pyloroduodenal Nerve Supply in the Surgery of Duodenal Ulcer, *Ann Surg* **81** 939-948 (May) 1925

51 Mayo, C H. Division of the Vagi for Pylorospasm, *Ann Surg* **88** 669-671 (Oct) 1928

52 Pieri, G., and Tanferna, U. Studi sulla fisiologia dell'innervazione viscerale dell'uomo II. Effetti della resezione del vago sulla secrezione gastrica, *Riforma med* **46** 323-326 (March 3) 1930

53 Pieri, G. Bilateral Sub-Diaphragmatic Resection of the Vagus Nerves, *Ann Ital di chir* **11** 53 (Jan 31) 1932, abstracted *J A M A* **98** 1950 (May 28) 1932

54 Dragstedt, L R., and Owens, F M., Jr. Supradiaphragmatic Section of Vagus Nerves in the Treatment of Duodenal Ulcer, *Proc Soc Exper Biol & Med* **53** 152-154 (June) 1943

55 (a) Thornton, T F., Jr., Storer, E H., and Dragstedt, L R. Supradiaphragmatic Section of the Vagus Nerves Effect on Gastric Secretion and Motility in Patients with Peptic Ulcer, *J A M A* **130** 764-771 (March 28) 1946 (b) Dragstedt, L R. Some Physiological Principles in Surgery of the Stomach, *Canad. M A J* **56** 133-137 (Feb) 1947 (c) Moore, F D., Chapman, W P., Schulz, M D., and Jones, C M. Transdiaphragmatic Resection of the Vagus Nerves for Peptic Ulcer, *New England J Med* **234** 241-251 (Feb) 1946 (d) Walters, W., Neibling, H A., Bradley, W F., Small, J T., and Wilson, J W. Gastric Neurectomy for Gastric and Duodenal Ulceration, *Ann Surg* **126** 1-13 (July) 1947 (e) Colp, R., in discussion on Walters, W. Vagotomy for Peptic Ulcer, *Proc Staff Meet, Mayo Clin* **22** 281-289 (July 23) 1947

COMMENT

Wood has pointed out that peptic ulcer in the British Isles, as elsewhere, is steadily on the increase He said that the incidence of perforation observed in hospitals of West Scotland had more than doubled from 1924 to 1941 During bombardments of World War II the incidence of perforation was particularly high, and he implied that this serves to emphasize the importance of psychosomatic factors in the causation of peptic ulcer In reviewing the pathogenesis of gastroduodenal ulcer in 1942 Dragstedt reminded that section of the gastric nerves has long been practiced in the treatment of this disease but that the effects of the operation on continuous night secretion do not seem to have been investigated Following his wide application of denervation over a three year period he stated "Results are so satisfactory and the physiologic concepts back of the operation so appealing that I feel even at this early date warranted in recommending trans-thoracic section of the vagus nerves as a substitute for subtotal gastrectomy in the treatment of duodenal, jejunal and proved gastric ulcers"⁵⁴

Although Dragstedt has joined Sippy,⁵⁶ Winkelstein and others in the opinion that excessive night secretion is one of the great problems in treatment and that among patients with ulcer the amount and degree of acidity of this secretion are almost invariably more than normal, there is no universal agreement on this matter Sandweiss, Sugarman, Podolsky and Friedman⁵⁷ recently have studied a group of normal persons and compared their results with those for a group of patients who had ulcer Employing continuous suction they found acid juice in both groups at night regardless of ulcer diets, and only 1 patient with ulcer had a tendency to hypersecretion Intermittent aspirations revealed greater volume of secretion among the patients with ulcer which these workers have interpreted as simply meaning delay in gastric emptying

Babkin and Karp⁵⁸ stated that whatever gastric hypersecretion may be—a cause or a symptom of peptic ulcer—it is evident that for therapeutic purposes it is most desirable to reduce the amount in patients with ulcer They took a rather pessimistic view of the effectiveness of all forms of medical or surgical treatment at present and

56 Sippy, B W Gastric and Duodenal Ulcer Medical Cure by Efficient Removal of Gastric Juice Corrosion, *J A M A* **64** 1625-1630 (May 15) 1915

57 Sandweiss, D J , Sugarman, M H , Podolsky, H M , and Friedman, M H F Nocturnal Gastric Secretion in Duodenal Ulcer, *J A M A* **130** 258-265 (Feb 2) 1946

58 Babkin, B P , and Karp, D Effect of Quinine and Atabrine on Gastric Secretion A Preliminary Communication, *Canad M A J* **56** 137-141 (Feb) 1947

stated that the search for new drugs or surgical procedures to diminish secretory activity of the gastric glands is justifiable.

In spite of the low reported mortality for gastric denervation fatal results have occurred when the procedure has been used alone⁵⁹ or combined with sympathectomy⁶⁰. Ulcers may progress and perforate silently into the peritoneal cavity⁶¹ or death may result from the usual complications of abdominal or thoracic operations. Disturbances of function were noted by many of the early workers in this field and have been reported on many occasions since 1937, when Adams and Phemister performed the first successful resection of the lower part of the esophagus, which involves also complete division of the gastric nerves. In such cases Churchill and Sweet mentioned the occurrence of tachycardia, sweating, gastric dilatation and atony, pylorospasm and sometimes an unexplained inanition without the presence of residual carcinoma.⁶² All these symptoms, in addition to diarrhea, gastric retention, fulness, belching and physiologic obstruction whose tenure has been rather unpredictable have been reported by various surgeons.⁶³ These disturbances of gastric motility have been the reason for the point of view that some form of drainage operation, such as gastroenterostomy or pyloroplasty, is necessary in many cases, and it is being employed routinely by many surgeons.

The abolition of any sensation of visceral pain by neurosurgical procedures is not fully understood at the present time,⁶⁴ and only a

59 Moore, F D, Chapman, W P, Schulz, M D, and Jones, C M. Resection of the Vagus Nerves in Peptic Ulcer. Physiologic Effects and Clinical Results, with a Report of Two Years' Experience, J A M A **133** 741-748 (March 15) 1947.

60 Weeks, C, Ryan, E J, and Van Hoy, I M. Two Deaths Associated with Supradiaphragmatic Vagotomy, J A M A **132** 988-990 (Dec. 21) 1946.

61 Walters, W, Neibling, H A, Bradley, W F, Small, J T, and Wilson, J W. Favorable and Unfavorable Results of Gastric Neurectomy (Vagotomy) for Peptic Ulcer. An Anatomic, Physiologic and Clinical Study, S Clin North America **27** 885-904 (Aug.) 1947.

62 Churchill, E D, and Sweet, R H. Transthoracic Resection of Tumors of the Stomach and Esophagus, Ann Surg **115** 897-920 (June) 1942. Sweet, R H. Transthoracic Resection of Esophagus and Stomach for Carcinoma. Analysis of Postoperative Complications, Causes of Death, and Late Results of Operation, ibid **121** 272-284 (March) 1945.

63 Grimson, K S, Baylin, G J, Taylor, H M, Hesser, F H, and Rundles, R W. Transthoracic Vagotomy. The Effects in Fifty-seven patients with Peptic Ulcer and the Clinical Limitations, J A M A **134** 925-932 (July 12) 1947.

64 Grimson, K. S., Hesser, F. H., and Kitchin, W. W. Early Clinical Results of Transabdominal Celiac and Superior Mesenteric Ganglionectomy, Vagotomy, or Transthoracic Splanchnicectomy in Patients with Chronic Abdominal Visceral Pain, Surgery **22** 230-238 (Aug.) 1947.

few reports have appeared. The individual response of the patient and the extent of the resection of the nerves are variables which have apparently complicated any evaluation of such results of gastric neurectomy.⁶⁵ The Hollander insulin test is the best available means of ruling out incomplete denervations in clinical data.⁶⁶ Many physicians feel that the loss of visceral pain is a disadvantage to the patient with ulcer who may be encouraged to exceed himself and to avoid proper medical surveillance. In certain patients who have undergone sympathectomy recrudescence of peptic ulceration has developed,⁶⁹ and progression of peptic ulcer also has been reported after vagotomy.⁶⁷ In the opinion of some surgeons this disturbance of autonomic balance between the sympathetic and parasympathetic nervous systems is not without hazard to the patient and also may account for the irregularity of reported results. It has also been suggested that vagal interruption renders hypertension more rapidly progressive.⁶⁹

SUMMARY

The salient points noted on review of the literature may be summarized briefly as follows:

The results of experimental gastric denervation have been recorded for at least one hundred and thirty-three years, and gastric denervation in various forms has been employed for the clinical relief of pain, hypersecretion and hypermotility for about fifty years.

Vague terminology has confused the descriptions of surgical anatomy and surgical technic used in these procedures. Results of the operation on healthy animals of various species have been compared indiscriminately with those obtained by the operation on ailing human beings, and long term observations frequently have been contrasted loosely with immediate postoperative results.

Dragstedt and his followers have revived interest in gastric denervation and have instigated the first large scale evaluation of hundreds of clinical cases.

The indications for the operation have varied with the various series, and unfavorable results are apparently related to this factor.

65 Lehman, E. P., in discussion on Walters, Bradley, Neibling, Small and Wilson,^{55d} *Ann. Surg.* **126** 1-18 (July) 1947

66 Dragstedt^{55b} Hollander, F. The Insulin Test for the Presence of Intact Nerve Fibers After Vagal Operations for Peptic Ulcer, *Gastroenterology* **7** 607-614 (Dec) 1946

67 Hallenbeck, G. A., and Priestley, J. T. Transthoracic Vagotomy Notes on Unsatisfactory Results in Two Cases, Proc Staff Meet, Mayo Clin **22** 332-336 (Aug 6) 1947 Warren, R. Experiences with Vagotomy for Peptic Ulcer, with Report of an Unsuccessful Case, *Surgery* **22** 246-258 (Aug) 1947

Gastroenterostomy and pyloroplasty are employed frequently as drainage operations in combination with the operation. They are designed to combat the attendant hypomotility of the stomach, especially when organic pyloric obstruction exists.

In the literature reviewed it was generally agreed that gastric denervation is efficacious in the treatment of gastrojejunal ulceration, but there is no general agreement concerning the direct loss of sensation of visceral pain which follows division of the gastric nerves. These effects have been ascribed to reduced motility of the stomach and also to interruption of sympathetic afferent nerves.

The Hollander insulin test is a reliable but not infallible means of demonstrating complete division of the gastric nerves. The use of this test has clarified clinical investigation in ruling out inadequate resections.

In addition to the treatment of peptic ulceration, gastric denervation has been employed with satisfaction in the treatment of intractable pain from chronic pancreatitis and carcinomatosis. Fatal results have followed the operation in hypertensive patients and after sympathectomy.

Insufficient time has elapsed to indicate the permanency of the favorable and unfavorable results of this operation and its proper place in the therapy of peptic ulcer.

DISCUSSION OF PAPERS ON PEPTIC ULCER

DR MORTON GROSSMAN, Chicago. I should like to call attention to the pronounced difference in the results with oral administration of enterogastrone as reported by Dr Ivy and myself and as reported by Dr Saltzstein. Twenty dogs on which the Mann-Williamson operation had been done were treated by the oral administration of enterogastrone, and in 5 of these dogs jejunal ulcers developed; another 10 dogs have died in an average of nine months without formation of ulcer after operation, 5 animals are still alive at an average of eighteen months after operation. After the treatment had been carried out for nine months it was discontinued, so the animals now living were treated for nine months and have gone nine months without treatment and have not contracted ulcer in that time. I cannot offer an explanation for the discrepancy in these results, but I should like to offer some suggestions as to where the cause of the discrepancy might lie.

We used a different diet, which included raw pancreas and liver, for the dogs on which the Mann-Williamson operation had been done. This provides a means of counteracting the nutritional deficiencies which these dogs suffer because of diversion of the pancreatic juice. This may be a factor of importance because the animals may not be able to survive long enough without such nutritional supplement for the action of the enterogastrone to occur. We are not able to test the efficacy of each batch of the material, and since it is a labile material the possibilities are that at times we use inactive material. We are at present devoting a great deal of energy to the development of rapid assay of each batch of material for its effect against formation of ulcer.

The beneficial effects of the administration of enterogastrone cannot be ascribed with certainty to the substance in it which depresses gastric secretion. The

effect against formation of ulcer is probably not caused by depression of gastric secretion. Nevertheless, inasmuch as in each case we have a substance which is able to manifest both activity against ulcers and secretory-depressant effects, until these have been isolated and shown to be separate substances, we cannot say that the effects are due to separate substances. No one has yet succeeded in preparing an extract of urine or intestinal mucosa which is effective against experimental ulcer but which is devoid of gastric secretion-depressant activity.

DR R ARNOLD GRISWOLD, Louisville, Ky. My personal experience with vagotomy is limited to 30 cases. The clinical results have been satisfactory. The procedure is still in the investigative stage, and those clinics that have facilities available should consider this as a research project and do more in the way of physiologic research than is being done in some places.

We have heard a great deal about acid today. This is really not what we mean. What is meant is the peptic power of the gastric secretion, that is, its ability to digest protein, even the protein of the gastric and duodenal wall. Gastric secretion caused by stimulation of the vagus nerve is a secretion high in hydrochloric acid and high in pepsin. Secretion stimulated by the hormone gastrin is a secretion which is high in hydrochloric acid but low in pepsin. I should like to suggest that peptic power be investigated more thoroughly than it has been. All of these studies are important in evaluating this new procedure and correcting any failures which we may have. The simple use of an ordinary test meal is not adequate if we are going to come to valid conclusions concerning vagotomy.

DR JOHN B HARTZELL, Detroit. In 1928 or 1929 a group of dogs was trained to swallow a stomach tube. They were given test meals and then the gastric contents were aspirated. Normal curves were obtained for free and total acidity and pH values. The right and left vagus nerves were then cut above the diaphragm, and gastric analyses were made. In each instance the free and total acids were much lower with a corresponding rise in pH values. Observations were made for eight months and the findings were rather constant. Two and a half years later these animals were reexamined and were found to have marked dilatation of the stomach, and in some cases the acid had returned. Similar observations have been made by other men.

Operations such as vagotomy have been performed for duodenal ulcer as far back as 1924. Vagotomy was not popular at that time because the surgeons feared gastric atony and dilatation following operation. Dr Charles H Mayo early did a partial vagotomy below the diaphragm with other operations on the stomach. I mention this as it might be of some interest as an indication of how this operation has progressed.

It has been a pleasure and a privilege to be present during the presentation of these papers. It is difficult, I think, at the present time to be certain just what our opinion will be about this procedure five years hence. Only time will tell.

DR I F STEIN JR, Chicago. On the surgical service of Dr Karl A Meyer at the Cook County Hospital twenty-four patients with peptic ulcer for which surgery was indicated have had section of the vagus nerves. Most of these patients have had thorough preoperative and postoperative studies. The first 5 were tested for vagal continuity by means of the subcutaneous injection of insulin, but the results were inconstant. Nineteen patients have been tested with a modification of the Hollander test (intravenous injection of insulin). Three of 6 patients with transthoracic vagotomy have had incomplete section of the vagus nerves, one of thirteen transabdominal operations was incomplete. The Hollander test,

in which insulin is injected intravenously, has been modified by (1) simultaneous studies of gastric motility and (2) a one hour control period of basal secretion and motility before the insulin is given. Following vagotomy, the presence of spontaneous or insulin-induced hunger contractions of type 1, 2 or 3 is indicative of incomplete vagotomy. This test is particularly useful after vagotomy for marginal ulcer following gastric resection, for the acid response of the patients is usually inconstant.

Motility studies with a balloon in the stomach have confirmed the work of Machella and others that "urecholine" (carbamimoyl-beta-methylcholine chloride) increases gastric motility after complete section of the vagus nerves. Similar studies have shown that "doryl" (carbamimoylcholine) promotes marked but temporary increase in gastric motility after vagotomy when given subcutaneously (0.25 mg). "Doryl" when given by mouth (2 to 3 mg) usually increases gastric motility for an hour or more. Both "doryl" and "urecholine" are useful in the treatment of gastric retention following complete vagotomy.

DR PAUL HARPER, Chicago. One point which I wish to comment on is that our series of patients differs from Dr Moore's in the incidence of diarrhea following gastroenterostomy. After vagotomy alone, about 50 per cent of the patients had some sort of diarrhea, while after vagotomy plus gastroenterostomy, we noticed this in only 15 per cent. What the explanation is for the difference between our observations and those of Dr Moore I am at a loss to say.

There is another side effect which we have encountered in 15 per cent of the patients on whom we have done gastroenterostomy. This is a symptom complex characterized by weakness, sweating and the feeling of faintness within a half-hour or so following a meal, which has been rather disabling in 3 cases. In 2 cases, it was accompanied by diarrhea following each meal, which was moderately distressing. We attribute this to the fact that a dumping stomach caused these reflex symptoms from sudden distention of the jejunum, and we feel that this might be a reason for leaning away from doing gastroenterostomy routinely with vagotomy.

In considering the evaluation of these patients postoperatively as to whether they have a complete vagotomy, we do not feel that any one test is completely reliable. We feel that the insulin test has great value when the insulin is given intravenously. We have been using this test for the past two years, using 16 to 20 units intravenously, and we always attempt to demonstrate a positive response preoperatively. We have found that, on repeating the insulin test and giving occasionally as much as 40 units intravenously, we can get positive tests in 96 per cent of our cases before operation. We have tried sham feeding, but this test, while more physiologic, is less reliable. Of the postoperative reduction of the quantity of hydrochloric acid that is put out in the night gastric aspiration seems the most reliable criterion. If the output of hydrochloric acid is not reduced after operation, it seems to us fairly certain that the patient did not get a complete vagotomy. The appearance of symptoms of gastric retention is not a good criterion of vagotomy, as these have occurred in patients with positive reactions to insulin tests. We feel that all these factors should be considered in trying to decide whether the patient has a complete vagotomy or not.

DR. WALTER WALTERS, Rochester, Minn. I should like to congratulate Dr Grimson on his excellent studies on patients who have undergone vagotomy. I have wanted to do this since the time I read his first article. That was one of the most complete studies on a current clinical problem that I have known. To that

now must be added these fine studies that Dr Moore has carried out at the Massachusetts General Hospital

Some of my studies have been incomplete because the insulin test was not made prior to and after vagotomy, so the results could not be compared. Dr Grimson said many months ago that postoperative studies of motility are an important part of the investigation of the results of the operation. It seems to me that investigating surgeons must proceed cautiously in application of these studies to clinical problems.

I am concerned about certain symptoms which develop after operations for duodenal ulcer. I want to call attention particularly to the symptom complex which Dr Harper described. These symptoms frequently are described as the vagotonic symptoms associated with a dumping syndrome. Quite obviously if the stomach is dilated a dumping syndrome—that is, the immediate passage of the gastric contents into the loop of the jejunum anastomosed to the stomach—is not present unless it can be demonstrated by roentgenoscopy. With the use of "urecholine," which stimulates peristalsis by means of the sympathetic nerves, we can offer a patient whose stomach is dilated after vagotomy a great deal of relief. We must admit that we do not know what causes the weakness, faintness and sweating that occur after vagotomy. Just before I left my office I had a letter from a physician concerning a case in which I performed vagotomy and in which a similar complex developed. I do not know what to do for the patient.

Apropos of new surgical methods of treating gastric and duodenal ulcer, Somerville, of India, has recommended ligation of the major arteries to the stomach. In a recent report published in the *British Journal of Surgery* he stated that the results have been commendable in 28 of 80 cases. Recently I reviewed an article in which gastric ulcer was produced experimentally in a high percentage of animals by ligating the gastric artery, so apparently the neurophysiology of the stomach, duodenum and intestine is not too well known. I think that for the present most of us should continue to use the recognized methods of surgical treatment for gastric ulcer. The superiority of vagotomy over other standardized procedures in the treatment of duodenal ulcer still has to be proved. Its greatest value, at present, seems to me to be in the treatment of recurrent ulceration, especially after partial gastrectomy and possibly after gastroenterostomy, especially if in conjunction with vagotomy the gastroenteric stoma is to be obliterated and the recurring ulcer removed.

DR FRANCIS D MOORE, Boston. I think that there has been a great deal of useful information mentioned here and I wish to thank the essayists and discussers for a most interesting afternoon.

Dr Hartzell's comments were most interesting. In fact it was his early study that influenced us to take up these studies before we knew of Dr Dragstedt's work.

I heartily agree that there is no single test for determining the efficacy of vagotomy. The best maneuver is to do a careful resection with adequate surgical exposure, in a leisurely and thorough fashion. I am sure that all of us are going to miss fibers in some cases and have troubles as a result. But these difficulties will be at a minimum if all who do this operation approach it as an anatomic challenge, and carry out preoperative and postoperative studies of secretion. The "thirty minute vagotomy" is a real threat in this field, and we must do all that we can to discourage it.

DR KEITH S GRIMSON, Durham, N.C. The excellent reports of the essayists and the interest of the discussers are appreciated. It has been suggested that

the insulin test is not a reliable index of the completeness of vagotomy. Under the conditions with which our tests have been run and at some time during a six hour period about one third of the patients exhibited an increase of free acid. Variations have also occurred in consecutive tests on the same patient. Alteration of the response to insulin has been observed after subtotal gastric resection without vagotomy. Evidence is therefore confusing except that patients may have an excellent result from vagotomy even though they respond to insulin hypoglycemia.

Conventional usage seems to have established the term vagotomy for both transthoracic and transabdominal approaches. This probably is not a misnomer, since the physiologic effect is produced by division of the nerve and evidently little altered by variations of technic designed to prevent regeneration. Our technic includes resection of long segments of the nerve, but unlike operations on the thyroid, pancreas or stomach, this does not add to the physiologic effect.

USE OF BUFFER THROMBIN IN THE TREATMENT OF GASTRIC HEMORRHAGE

A Preliminary Report

BYRNE M DALY, MD
DETROIT

SINCE the first use of thrombin in clinical medicine¹ in 1939, it has been used under a variety of circumstances for the control of bleeding. It is now generally available commercially, and its successful use in any particular situation generally requires that it be applied with the use of technics which take into account the properties of thrombin and the nature of the bleeding and its location. Its clinical application in supportive therapy for bleeding of the upper part of the gastrointestinal tract has not been considered feasible because of the acidity of the stomach. Without special precautions this high acidity will not only prevent thrombin from clotting fibrinogen but will also destroy the thrombin. A simple and practical technic has been developed which overcomes this difficulty, and evidence has been obtained which shows that thrombin is useful in the control of gastric hemorrhages.

PROPERTIES OF THROMBIN

This powerful clotting agent acts in a natural manner to clot fibrinogen directly. The concentrates now available commercially will accomplish this in a few seconds. There is, however, interference with the rate of clotting in solutions more acid than p_H 6.5, and in addition, at p_H 4.3 the enzyme is destroyed.² In alkaline solution there is a greater range of maximum activity than on the acid side of neutrality. The dried powder is stable for a period of years, but in aqueous solution full activity is maintained only a few days. Since thrombin is easily

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1 Warner, E D, Brinkhous, K M, Seegers, W H, and Smith, H P Further Experience with the Use of Thrombin as a Hemostatic Agent, Proc Soc Exper Biol & Med 41 655-657 (July) 1939

2 (a) Seegers, W H Purification of Prothrombin and Thrombin Chemical Properties of Purified Preparations, J Biol Chem 136 103-111 (Oct) 1940 (b) Seegers W H, and Smith H P Factors Which Influence the Activity of Purified Thrombin, Am J Physiol 137 348-354 (Sept) 1942

destroyed by a variety of factors it could not be assumed to be stable in phosphate buffers or in the stomach of patients after successful neutralization of the acidity of the stomach.

METHODS

The first step in this work was concerned with the measurement of thrombin activity in seventh-molar phosphate buffer (20.4 Gm of disodium phosphate [Na_2HPO_4] in 1 liter of water plus 1.95 Gm of potassium dihydrogen orthophosphate [KH_2PO_4] in 100 cc of water) at room temperature. The contents of one ampule of thrombin (bovine) topical³ were dissolved in 30 cc of this buffer, and the thrombin activity was then measured quantitatively by the method described by Seegers and Smith.^{2b} Repeatedly the stability was found to be approximately the same as in isotonic solution of sodium chloride.

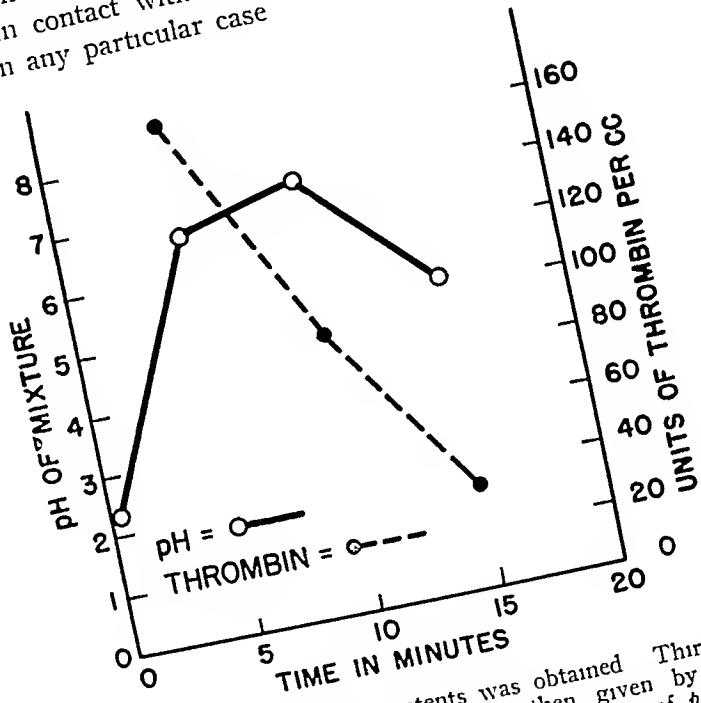
In order to show that the gastric contents could be buffered to a p_{H} required by the properties of thrombin, a total of 35 normal and hospitalized patients were studied.

Within thirty to forty-five minutes of the noon meal, a Levine tube was passed and the contents of the stomach were aspirated with the patient lying on his left side. All this was discarded except 10 cc which was retained as the initial specimen for p_{H} (Beckman, glass electrode) determination. Then 30 cc of seventh-molar phosphate buffer was given by mouth, and after five minutes a specimen of 10 cc was withdrawn to determine the p_{H} again. This then served as a measure of the efficiency of the buffer. Then 10,000 units of thrombin was dissolved in 30 cc of the buffer, and this was given by mouth. A small specimen was then immediately taken for thrombin analysis. Exactly five minutes later a specimen was again taken. Its acidity was measured and the thrombin activity was also measured. Five minutes later, the final specimen was taken and the same tests were made.

Of the 35 cases, it was found that 31 showed thrombin to be present five minutes after administration in concentrations ranging from 1 unit to 150 units per cubic centimeter. In 3 cases the thrombin was not present despite a rise in p_{H} to within the range of thrombin activity. The thrombin may have passed the pyloris. One case failed to show the usual strong shift in p_{H} , and the thrombin was destroyed. The chart shows the values for p_{H} and thrombin concentration for 1 of the subjects studied. It represents a selected case which I consider to be midway between my best and poorest result. This showed that the activity of thrombin, placed in the stomach, remains for a time sufficient for any blood with which it might come into contact to be clotted in a few seconds. If, then, the thrombin were to gain access

³ The thrombin (bovine) topical was prepared by Parke, Davis & Company.

to a bleeding point or locus of oozing the desired hemostatic effect could be anticipated. Effective hemostasis with thrombin is secured by having blood clot quickly as it emerges from the tissues. The clot then becomes anchored in and on the tissue surface. It therefore seemed more important to have a high concentration of thrombin for at least a few minutes than to have active thrombin for long periods of time. There must of course be ample time for the thrombin to come into contact with an extensive portion of the stomach surface so as to increase the chances of its coming in contact with the site of bleeding wherever it might happen to be in any particular case.



At zero time a sample of gastric contents was obtained. Thirty cubic centimeters of seventh-molar phosphate buffer was given by mouth. Five minutes later a small sample was aspirated for determination of pH . Immediately 10,000 units of thrombin topical was given with 30 cc of phosphate buffer. Then and at five minute intervals, specimens were taken for analysis of thrombin and pH .

My colleagues and I were curious to know how long thrombin activity remains in buffered gastric juice. Three specimens were placed in the refrigerator at 8°C for twenty-four hours. A loss of approximately 30 per cent of the total units of thrombin originally present was found. The result was more favorable than anticipated. Apparently the acidity of the gastric juice is the primary factor to be dealt with. This *in vitro* experiment cannot, of course, be interpreted to mean that thrombin would remain active in the stomach for twenty-four hours.

CLINICAL RESULTS

The patients treated were selected so as to represent only those who had a history of hematemesis with a definite picture of acute loss of blood. They had vomited blood prior to and/or during admission. The average hemoglobin value was 72 Gm and the average red cell count 2,700,000. The patients were given 30 cc of seventh-molar phosphate buffer, $p_{H_2} 7.6$, in order to neutralize and buffer the gastric contents. After five minutes this was followed by another 30 cc of the buffer, containing 10,000 units of thrombin, or roughly 330 units per cubic centimeter.

Of the 21 patients treated 12 responded to the initial dose. They showed no further evidence of continued loss of blood. There was obvious improvement as shown by pulse rate, increase in blood pressure, increased red cell count and other clinical signs during an average of eleven and one-half days of observation in the hospital.

Five patients responded only after two or more doses. The fact that they did not respond to the first dose was plainly to be judged from their continued distress and further vomiting, all of which subsided after more attempts to remedy the situation with thrombin. Then they showed general improvement.

Four patients failed to respond and were operated on. The following observations were made. The first patient had pronounced hemorrhagic gastritis and esophageal varices. A clot of about 700 cc was seen in the stomach. The second patient had a duodenal ulcer, and the thrombin may not have reached the bleeding point. The third patient also had a duodenal ulcer, which had eroded into the pancreas. The bleeding vessel was large and required ligation during the surgical procedure. The fourth patient had massive esophageal varices and advanced cirrhosis of the liver.

With a problem of this nature it is obviously difficult to evaluate the effectiveness of the new procedure. Thus far I have stated that thrombin can be recovered from the stomach and that there are good reasons for judging that thrombin was effective in 17 out of 21 patients. For further orientation it seemed appropriate to select, at random, from the records of the same hospital, 21 patients with bleeding ulcer not treated with thrombin. This was done and according to these records 10 patients showed no evidence of bleeding after admission, 10 showed continued episodes of bleeding, and 1 died of hemorrhage.

It is well known that bleeding peptic ulcers are variable in the amount and frequency of loss of blood. This uncertainty presents a definite hazard. Were it not for the fact that evidence of arrest of hemorrhage followed shortly after the administration of the buffer thrombin solution it might be argued that those patients in whom there was no subsequent bleeding might not have bled any more even without

treatment. A much larger series of patients would be necessary definitely to establish this point, but we believe that in this group of cases excessive losses of blood have been prevented by a simple and harmless procedure.

SUMMARY

From the clinical and laboratory experience gained so far, it is concluded that thrombin is definitely an aid in the control of gastric hemorrhage when the content of the stomach is buffered. Both the buffer and the thrombin are palatable and are nontoxic. It is realized that a series of patients is necessary for a thorough evaluation of this treatment, and the work is being continued. Heavy arterial bleeding and bleeding which ordinarily requires a ligature cannot be controlled by this substance alone. When thrombin does not alleviate gastric hemorrhage after four or five doses, it is felt that immediate surgical intervention is indicated.

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PROGRESS IN ORTHOPEDIC SURGERY FOR 1945

A Review Prepared by an Editorial Board of the American Academy of Orthopaedic Surgeons

XXII AMPUTATIONS, APPARATUS AND TECHNIC

Prepared by

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THIE SAME trend toward discussions of acute trauma in orthopedic literature has continued in 1945 as in the previous war years especially as regards amputations and to a somewhat less extent fractures, for obvious reasons. In this section of the "Progress" as many articles on amputations were published as those on both apparatus and technic, the other two subtitles in our assignment.

Relatively few old line orthopedic articles appeared until well into 1946, these will be reviewed in next year's "Progress." A great many of these articles originated in military circles, where many of our more talented surgeons have been serving for several years and have gained special experience which will be of real value in civilian life. Next year there will be many less military articles as these men get out of uniform, but even so many will be reporting their wartime experiences.

Amputations—Most of the articles on amputations hew true to the line, but there are a few articles that depart from conservatism. Such a one⁸⁰⁴ describes a routine amputation procedure in the mid thigh but leaves $\frac{3}{4}$ inch (19 cm) of bone protruding from the purse-stringed closure. Apparently unmindful of the osteoclastic action at the level of the skin, this author was hoping to attach a prosthesis early to this bony projection and start immediate end bearing. He closes with the comforting statement that "further study will be necessary to determine how the skin and bone will react to each other and the new conditions." The only amputation reported in this brief article of this nature was on a rabbit.

The painful phantom limb syndrome was discussed at least four times, all the authors advising against further local surgical treatment without

⁸⁰⁴ Citron, R. R. New Method of Amputation and Fitting of Prostheses, Peoria M News 16 13 (March) 1945

thorough study⁸⁰⁵ and most of them concluding that the symptoms were of central rather than peripheral origin

In an excellent article by Randall, Ewalt and Blair,^{805c} the psychiatric reactions of the amputee is discussed. While this phase of the problem does not strictly come within our scope, it is urged that the article be read in full. In addition to discussing the "phantom limb" in the usual manner, the authors divide the psychiatric reactions into three phases—the immediate or first postoperative period when the patient should feel grateful that his life was saved, the intermediate period, during the usual revision of the stump, when the patient is in doubt about the future (this the authors feel is the truly critical period) and the late or final reaction when the patient has adjusted himself or not psychiatrically to the rapid tiring of the member and inability to be on his feet for a long time. The authors urge the acceptance of these persons in a humane way by their associates and community.

The increasing popularity of ice anesthesia in amputations, particularly those involving diabetes and arteriosclerosis, is shown by the number of articles that continue to appear⁸⁰⁰

Mock⁸⁰⁷ reports a case in which a tourniquet was left on a refrigerated extremity for three and one-half hours because of unavoidable circumstances without deleterious effect on the tissues.

For any one particularly interested in ice anesthesia, the description by Cayford and Pretty⁸⁰⁸ of the technic employed at the Montreal General Hospital is well worth reading. It is far simpler than the usual technic and one of us has used a similar procedure several times with complete satisfaction.

805 (a) Williams, G A Phantom Limb Syndrome Complicating Pregnancy and Puerperium, Am J Obst & Gynec **50** 546-547 (Nov) 1945 (b) Livingston, K E Phantom Limb Syndrome Discussion of Role of Major Peripheral Nerve Neuromas, J Neurosurg **2** 251-255 (May) 1945 (c) Randall, G C, Ewalt, J R, and Blair, H Psychiatric Reaction, J A M A **128** 645-652 (June 30) 1945 (d) Herrmann, L G, and Gibbs, E. W Phantom Limb Pain Relation to Treatment of Large Nerves at Time of Amputation, Am J Surg **67** 168-180 (Feb) 1945

806 Paterson, F M S Refrigeration Anesthesia in Diabetic Surgery, Proc Am Diabetes A (1944) **4** 141-167, 1944 Dennis, C For Amputation of Thigh Ice Anesthesia, Hospitals **19** 83-84 (Aug) 1945 Melick, D W Refrigeration Anesthesia, Am J Surg **70** 364-368 (Dec.) 1945 Lam, C R Refrigeration Anesthesia, Arch Phys Med **26** 20-22 (Jan) 1945 Shaar, C M, Jones, D T, and Lehan, T R Refrigeration Anesthesia, S Clin North America **24** 1326-1336 (Dec) 1944 Jewett, E L Skin Traction for Amputation Stump, U S Nav M Bull **44** 629-632 (March) 1945

807 Mock, H E Refrigeration in Trauma Report of Nine Year Old Patient with Lower Extremity Gangrene Following Dislocation of Distal Femoral Epiphysis, Am J Surg **67** 424-435 (Feb) 1945

808 Cayford, E, and Pretty, H G Refrigeration Anesthesia and Evaluation of Amputation Sites by Arteriogram, Ann Surg **121** 157-163 (Feb) 1945

Another excellent article of general interest on refrigeration in trauma of the extremities is by McElvenny,⁸⁰⁹ who writes exhaustively on the subject and should be read by all who are interested. An excellent review of the literature is presented as well as practical points in the technic. Nothing, however, is brought out that has not been indicated in previous articles.

Most of the articles discussing the technic of amputations stress the need for the avoidance of excess muscle at the end of the stump and advise the cutting of the muscle at the level of the bone and wedging the inner cone leaving only deep fascia and skin to cover the bone ends. Another point that is justifiably mentioned in most articles discussing the technic is the necessity and value of skin traction.

The controversy about the treatment of nerve ends continues. Kirk's recent statement that there is no ideal way seems to hold true. In view of this, it seems to us that the best way is probably the simplest, i.e., the transverse severance of the nerve with a sharp scalpel an inch (2.5 cm.) or so proximal to the distal cut surface of the muscle. An enumeration of various ways of treating nerve ends at amputation is given by Metz,⁸¹⁰ who himself advocates ligation with chromic gut to control bleeding, severing the nerve speedily with a sharp knife.

Brown⁸¹¹ discusses the details of the manufacturing of prostheses for the hand using "foamed latex mixtures." This is beyond the needs of the average orthopedic surgeon, but when one remembers this author's excellent exhibits at various medical meetings, one reads the article with much interest and is glad to know of someone to whom an occasional case may be referred.

For those surgeons interested in kinetic or cinematic operations, an encouraging article by Bartley⁸¹² is cited. In one clinic mentioned where these cases were looked up, 83 per cent of 403 patients on whom this operation had been performed were using their artificial arms. In another clinic surveyed by Kessler, the chief advocate of this operation, only 12 per cent of 278 arm amputees, who did not have a kinetic arm, were wearing an artificial arm for cosmetic purposes only, and only 2 were wearing a mechanical arm for functional use. In Germany five years after World War I a review was made of the 7,000 hand and arm amputees, and it was found that only 1.8 per cent were wearing any sort of mechanical arm for functional use.

809 McElvenny, R T. Refrigeration in Trauma of Extremities, *S Clin North America* **25** 192-209 (Feb) 1945

810 Metz, A R, in discussion on Herrmann and Gibbs^{805d}

811 Brown, A M. Prosthetic Restorations After Amputations About Hand, *Am J Surg* **68** 338-343 (June) 1945

812 Bartley, S P. Kinetic Amputations and Plastic Reconstructions of Fingers Operative Technic and Functional Results, *Am. J. Surg* **67** 181-183 (Feb) 1945

This argues in favor of the kinetic amputations, but it must be conceded that the technic is above the ability of the average surgeon

Realizing the tendency of the average patient to lay aside his arm prosthesis before he really knows how to use it, Olson⁸¹³ in a well written paper emphasizes the importance of prolonged instruction before the patient is allowed to be without supervision. This in civilian practice is much more difficult than in military or veterans' service. We believe that this author is incorrect when he states in this article that the waddling gait of a thigh amputee on a prosthesis is due to the weakening of adductor power. The reverse is really true, as the patient without the ability to abduct his limb because of the shortness of his stump has to put his center of gravity over this leg when he bears weight and the equivalent of a gluteus medius gait is the result. In general it is true that the longer the thigh stump is—as long as it does not include the condyles—in amputations above the knee, the better will a patient walk, everything else of course being equal.

Sugarbaker and Ackerman⁸¹⁴ feel that the major hind quarter amputation is not done as often as it should be and that the operation should depend more on the pathologic indications rather than the physical tolerance of the patient.

One paper on forequarter amputation was published by Berman,⁸¹⁵ who reported 5 cases. Three of the patients died within a year, and the other 2 were alive and well a year and a half after operation. A detailed description is given of the technic, which does not depart particularly from that employed by Pack⁸¹⁶.

This year there seems to be a dearth of articles on prosthesis, suggesting that a general understanding has been reached by both the military and civilian makers of prostheses. As regards preparing a stump of a lower extremity, Stevens⁸¹⁷ has designed a simple harness apparently superior to the usual "shrinker" aimed particularly for developing muscles above the site of amputation. The article is well illustrated.

813 Olson, P F Amputation During the War and After, *Surg, Gynec. & Obst.* **81** 688-691 (Dec.) 1945

814 Sugarbaker, E D, and Ackerman, L V Disarticulation of Innominate Bone for Malignant Tumors of Pelvic Paries and Upper Thigh, *Surg, Gynec & Obst.* **81** 36-52 (July) 1945

815' Berman, J K. Interscapulothoracic Disarticulation of Arm, *Surgery* **18** 256-266 (Aug.) 1945

816 Pack, G T, McNeer, G, and Coley, B L Interscapulothoracic Amputation for Malignant Tumors of the Upper Extremity Report of Thirty-One Consecutive Cases, *Surg, Gynec. & Obst.* **74** 161-175 (Feb.) 1942

817 Stevens, A G Exercise Harness for Use of Lower Extremity Amputees, *Physiotherapy Rev* **25** 27-29 (Jan -Feb) 1945

Apparatus—Once again, stimulated obviously by the opportunities of closer relationship between the surgeon and the brace shop in military service, many original pieces of apparatus have been devised and published officially from the various branches of our armed forces

In relation to plaster technic possibly the most important device since the advent of the use of plaster of paris casts in the early 1850's has appeared on the market. The reciprocating electrical plaster cutter devised by Stryker has made the removal and fenestration of plaster casts a pleasure. The sole drawback experienced by one of us in using this truly marvelous instrument is the disquieting noise made by the reciprocating mechanism. A description of the instrument has not yet appeared in print but most orthopedic surgeons have seen it on exhibit at the meetings of the Clinical Orthopedic Society and the Orthopedic Academy in October 1945 and January 1946, respectively.

The possibility of the use of this instrument to replace the dangerous rotating electric bone saw immediately occurs to the bone surgeon and it is hoped that it will be available in the not too distant future. Stryker is working on that now.

A refinement of the valuable cast wedging idea has been published by Rhinelander and Ropes,⁸¹⁸ who describe three types of hinges for use in correcting articular deformities, particularly of the knee and the elbow.

The chief advantage of this apparatus is that the leather strap type of plaster hinge has been replaced in one instance by a steel strap and in the other two instances by conventional hinges, one being fitted for gradual correction with a turnbuckle arrangement. One of us has in the past gotten along rather well simply by using a small uncut portion of the cast as a hinge, but admits that in some of the more difficult problems this more formal idea would be of real value. The article is well illustrated.

Two more walking plates for attachment to plaster casts have been devised,⁸¹⁹ both rather similar and having the same two objectives—a weight-bearing surface that is less noisy and not so hard on floors and a convex rocker bottom arrangement for ease in walking.

The *Army Medical Bulletin*, publishing an article by Harvey,⁸²⁰ describes a split drum for use in making plaster reinforcements, or

818 Rhinelander, F W, and Ropes, M W Adjustable Casts in Treatment of Joint Deformities, *J Bone & Joint Surg* 27 311-316 (April) 1945

819 Vineberg, A M, and Murphy, D R New Rocker Type of Cast Walker Preliminary Report, *Canad. M A J* 52 394-397 (April) 1945 Koven, B, and Koven, M T Walking Iron with Foot Plate, *Am J Surg* 68 270-271 (May) 1945

820 Harvey, R K Device for Making Plaster of Paris Reinforcements, *Bull U S Army M Dept*, June 1945, no 89, pp 118-119

splints as they are sometimes called. With the satisfactory commercial product, this device is not so necessary now as it formerly might have been.

A description of an improved Tobruk plaster was published in the *Bulletin of War Medicine*⁸²¹ by the editorial staff. It is of little moment in peacetime, but might be of considerable value in an emergency.

Rowe⁸²² recommends the use of used roentgen film strips (6 by 1 inch [15.2 by 2.5 cm]) to reinforce plaster casts. It is believed that others, including us, might express some doubt about this idea, as it is feared that the film strips are likely to weaken the plaster by preventing complete bonding together of all the layers of the plaster. It is mentioned here solely because the author is suggesting something which in his hands has been worth while. Possibly the emulsion on the roentgen ray film serves to bind the plaster and the film together.

Anderson and Erickson⁸²³ have come out with another plastic cast, this time a combination of "fiberglas" and cellulose acetate with a setting fluid. It is strongly recommended, but one wonders whether it will be more successful than the "castex" product, which is still used to some extent. The porosity and waterproofing of the product and imperviousness to roentgen rays are factors decidedly in its favor. Its use as a routine clinic supply is prevented by its cost together with its somewhat increased difficulty of application. This is apparently the same material that was reported the year before in *Northwest Medicine*⁸²⁴.

With all their disadvantages, it is difficult to improve on the old time plaster bandages, particularly the commercial type put out the last few years. We have wondered, as have often many others during hot summer days, whether some sort of tubing might be incorporated between the layers of a hip spica so that ice water might be run through, and were much interested in reading an article by Cromar,⁸²⁵ who has done this and considers it of value. Using perforated tubes and passing air through them, he mentions the possible use of an insecticide if found necessary.

821 Improved Tobruk Plaster (Mark III), Bull War Med 5 241-242 (Dec) 1944

822 Rowe, M L Easy and Economical Method of Making Removable Casts, J Bone & Joint Surg 27 521-522 (July) 1945

823 Anderson, R, and Erickson, H R, Glass Plastic Cast, Am J Surg 69 299-305 (Sept) 1945

824 Anderson, R New Waterproof Plastic Cast, Northwest Med 43 365-371 (Dec) 1944

825 Cromar, C D L Body Cooler for Use with Plaster of Paris Casts, J Canad M Serv 2 183-185 (Jan) 1945

A tentlike frame has been devised as a substitute for the time-honored Balkan frame. Its three originators⁸²⁶ claim in addition to the usual merits of the latter apparatus that it can be used as an oxygen tent. Aside from this and that less overhead room is needed, there seem to be no special merits that are not shared by the Balkan frame. One disadvantage is that, with the pitched roof type of overhead cross members, at least two extra cross members are required.

Holman⁸²⁷ has described a useful suspension bar for a Thomas splint when used on a stretcher. This supports as well as firmly stabilizes the distal end of the splint, adding materially to the safety and comfort of the injured extremity.

Spiegler⁸²⁸ advocates a simplified humeral splint, the fundamental parts of which are two rectangular pieces of sheet metal of proper size and gage and a malleable metal strip. One metal plate supports the humerus and the other, when the malleable metal strip is attached to both, holds the arm abducted when pressed against the side of the body. Both, of course, are properly padded and fitted with stabilizing straps, but the manner of supporting the forearm is not discussed except to state that "a collar and cuff, or cravat sling, may be applied from the neck to the wrist." It occurs to us that this splint might well be incorporated into an arm plaster and thus take the place of the difficultly applied shoulder spica. One of the illustrations shows a rather distressing amount of internal rotation of the forearm which is bound to occur if the forearm is not properly supported.

Andreasen⁸²⁹ describes a shoulder abduction splint using the Bohler-Cramer wire properly bent and padded. This is similar in construction and use to the efficient splint originally described by Bohler which every once in a while should be brought to our attention. As an immediate postoperative dressing, adhesive tape being used instead of straps, it is most useful. As the patient convalesces the adhesive tape can be gradually replaced by straps.

In line with the suggestion, Phalen⁸³⁰ incorporates a leg brace in a plaster spica for hip immobilization, particularly acetabular fractures. In his illustration, much more immobilization of the hip would have

826 Healy, W V, Peterson, C A, and Chapman, E St. Clare Fracture Frame Preliminary Report, *Indust Med* **13** 998-1000 (Dec.) 1944

827 Holman, M S Suspension Bar for Thomas Splint, *Lancet* **2** 434 (Oct. 6) 1945

828 Spiegler, A A Simplified Humeral Splint, *Am J Surg* **68** 268-269 (May) 1945

829 Andreasen, A T Simplified Shoulder Abduction Splint, *Lancet* **2** 600 (Nov 4) 1944

830 Phalen, G S Cast-Caliper Brace for Immobilization of Hip, *J Bone & Joint Surg* **27** 724-726 (Oct) 1945

been obtained had he carried the body part of his short spica well over the costal border. The idea is an excellent one, however, and is the reverse of what one of us has done on many occasions, i.e., he has attached a pelvic band or a body brace to a leg plaster by uprights connecting the two. Many occasions may develop in which this unconventional combination of plaster cast and brace may be employed.

A new embodiment of a method for preventing rotation in a brace for the cervical part of the spine when the need for actual support of the head does not exist has been published by Boldrey.⁸³¹ To a well fitting occipital plate, flanges are attached just below the lobe of the ear and extend forward around the maxillary bones to the ala of the nose. This gives the desired relief to motions of the mandible and yet prevents rotation of the head. The illustration shows the arrangement well.

Whigham⁸³² published the description of an ice-tong-like spring clip which for temporary Thomas splint traction to an injured leg can be quickly attached to a boot heel. He also suggests the use of a jacket sleeve as a Thomas splint sling.

In line with Bunnell's ideas relative to the value of mobilization splints, particularly for the hand, Feltner⁸³³ has devised a reversible easily made splint for forearm, wrist and finger facilitating the type of mobile splintage desirable for injuries of the peripheral nerves. The article is well illustrated. A somewhat similar but less easily understood apparatus was described by Herzog.⁸³⁴ This was devised particularly for radial nerve palsies rather than the more complicated finger involvements.

Technic—While there is nothing in it that has not been said before, it is felt that in a review of last year's literature Darrach's⁸³⁵ splendid article on "Surgical Approaches for Surgery of the Extremities" should start off this subtitle. He states that the criteria for a good surgical approach are as follows: (1) It should provide comfortable access to the structures sought for, (2) it should do as little damage as possible.

⁸³¹ Boldrey, E. Supportive Immobilization of Cervical Spine, *Surg., Gynec. & Obst.* **80** 107-108 (Jan.) 1945

⁸³² Whigham, J. R. M. Clip for Use with Thomas Splint, *Brit. M. J.* **1** 265 (Feb. 24) 1945

⁸³³ Feltner, J. B. Mobilizing Splints in Treatment of Motor Nerve Injuries, *M. Bull. Mediterranean Throat Op.* **2** 162-166 (Dec.) 1944

⁸³⁴ Herzog, E. G. Splint for Radial Nerve Palsies, *Lancet* **2** 754 (Dec. 9) 1944

⁸³⁵ Darrach, W. Surgical Approaches for Surgery of Extremities, *Am. J. Surg.* **67** 237-262 (Feb.) 1945

(3) it should pass between rather than through muscles, (4) it should pass these muscles opposite their blood and nerve supply, (5) it should permit actual visualization of important structures or pass a safe distance from them, and (6) it should be possible at the close of the operation to restore the disturbed structures to their normal position. He takes up particularly the shoulder, including the useful transacromial as well as the anterior and posterior approaches, the arm, the forearm, the thigh (exposing the femur) and the lower part of the leg. The importance of adequate length of incisions is stressed. Dr Henry Marble, of Boston in discussion stated all too truly that the length of an incision varies with the age of the surgeon.

One might say that this excellent article of Darrach's is a preface to Nicola's⁸³⁶ valuable book "Atlas of Surgical Approaches to Bones and Joints." Nicola's book has nothing particularly new in it, but it unquestionably is a stimulus in the progress of our specialty, especially with our junior members. As has been stated, a large part of the success of an operation depends on an adequate approach, and a surgeon would do well to consult this publication the evening before he embarks on a surgical procedure with which he is not perfectly familiar. It is a true vademecum.

Straub, Thompson and Wilson's⁸³⁷ paper on the results of epiphyseodesis and femoral shortening with the Phemister technic is of considerable importance and concern at least to the reviewer. The Phemister technic was employed in the arrest of growth and over one fifth of the patients experienced growth deformities, only half of them severe enough, however, to justify surgical correction. The inaccuracy of any known method of predicting growth of bone was justifiably stressed. White⁸³⁸ reported a series of cases in which a modification of Phemister's technic was employed consisting essentially of a deeper penetration of the cortex in the local bone grafting procedure, in which no deformities had developed. White had empirically figured on cessation of growth in girls to be at 16 years and that in boys a year later. Using this as a premise and figuring $\frac{3}{8}$ inch (about 1 cm.) retardation would result from epiphyseodesis of the femur and $\frac{1}{4}$ (0.6 cm.) at the proximal end of the tibia, he reported satisfactory results in his series of cases. It is obvious that further work must be done on this problem, particularly as regards the age at

836 Nicola, T. *Atlas of Surgical Approaches to Bones and Joints*, ed. 1, New York, The Macmillan Company, 1945.

837 Straub, L R., Thompson, T C., and Wilson, P D. Results of Epiphyseodesis and Femoral Shortening in Relation to Equalization of Limb Length, *J Bone & Joint Surg* **27** 254-266 (April) 1945.

838 White, J W., in discussion on Haas⁸³⁹

which, in a given case, growth of bone can be expected to be completed Todd's "Atlas of Bone Maturation of the Hand" is now being employed by White in ascertaining this age in individual cases

These authors were much more satisfied with their results after femoral shortening, none of them however in patients less than 13½ years of age, the average correction being a little short ($\frac{1}{8}$ inch [0.32 cm]) of 2 inches (5.1 cm)

Haas⁸³⁹ in another article on retardation of growth reported experiments on animals in which wire loops were used around the metaphysial plate through the diaphysis and epiphysis. He hopes to prove that by maintaining and releasing these wire loops, growth of bone can be controlled. This work is still in the experimental stage, and further reports will be made later. This research work is most important and will be followed with much interest.

Billig⁸⁴⁰ in an article discussing gradual progressive fascial ligamentous contractures with advancing years with their sequelae, such as sciatica, advises their release by physical therapeutic means including particularly stretching exercises. This is a good conservative article to read during the fortunately gradually waning furor about disk lesions.

Flanagan⁸⁴¹ has devised an instrument for measuring the depth of screw holes, facilitating the use of a screw of the proper length. Any rod of smaller caliber than the smallest hole that is likely to be bored through bone, with a slight hook on the end to catch on the deep end of the bone would do, but as we rarely have such a rod, it is an instrument that should be in the bone kit of those of us that use a good many bone screws.

Supporting McKeever's favorable attitude toward the use of cellophane where union of two adjacent structures is to be avoided, as in tendon work, Harley⁸⁴² reports 3 cases in which he has used it successfully (1) for making the tunnel for the long extensor of the index finger, (2) another for the adherence of the distal portion of the triceps to the humerus and (3) to prevent the recurrence of a synostosis between the radius and the ulna in a fracture. It is generally conceded, however by those doing most of this work that tantalum is the interposing material of choice.

839 Haas S L Retardation of Bone Growth by Wire Loop, *J Bone & Joint Surg* **27** 25-36 (Jan) 1945

840 Billig, H E, Jr Release of Fascial Ligamentous Contractures in Physical Rehabilitation, *Indust Med* **14** 270-273 (April) 1945

841 Flanagan, J J Instrument for Accurate Measurement of Bone Screws, *J Bone & Joint Surg* **27** 723 (Oct) 1945

842 Harley, G H, and Breck, L W Cellophane in Bone and Joint Surgery, *Am J Surg* **68** 229-231 (May) 1945

Another technic for rapid roentgenography in the operating-room has been published in detail by Minear⁸⁴³. This allows a readable film to be produced at a temperature of 75 F in one and three quarters minutes and in a minute less at 95 F. The dimensions of a portable light-proof box are given in this illustrated article, the technic requires only one solution. This technic to us is superior to other quick processes in which only one solution is employed.

Anderson⁸⁴⁴ has made a contribution to the technic of ankle fusion by suggesting the removal of the malleoli, which unquestionably sometimes keep the opposing surfaces of the talus and the tibia apart. However, he employs transfixing pins with fixation rods instead of simple plaster for immobilization and apposition. The incorporating of the pins in plaster meets with Anderson's approval, although he obviously does not feel that to be necessary.

An excellent review of the uses and dangers of a tourniquet for work on the extremities has been written by McElvenny⁸⁴⁵. He condemns the use of any but a pneumatic tourniquet for the upper part of the arm, and believes that the Esmarch tourniquet for the leg is better than the sheet rubber bandage. It is feared that the dangers of the tourniquet have been stressed so much that few general surgeons who read this article will use it. One of us caught himself worrying about the complications cited, in a recent case in which he used a so-called Martin sheet rubber bandage for the arm.

The added interest in spinal surgery and exploratory operations on the disks is reflected in the publishing of four articles describing somewhat similar spinal retractors, two of them self retaining. The essential principle in all of them consists in the fact that they go deeper and have different arrangement at their depth for holding the tissue away from the laminas. Meyerding,⁸⁴⁶ Shelden and Pudenz,⁸⁴⁷ Glaser⁸⁴⁸ and Hoen⁸⁴⁹ are the authors. Those particularly interested are referred to the original articles.

843 Minear, W. L. Rapid Roentgenography in Operating Room, *J Bone & Joint Surg* **27** 157-159 (Jan) 1945

844 Anderson, R. Concentric Arthrodesis of Ankle Joint Transmalleolar Approach, *J Bone & Joint Surg* **27** 37-48 (Jan) 1945

845 McElvenny, R. T. Tourniquet Its Clinical Application, *Am J Surg* **69** 94-106 (July) 1945

846 Meyerding, H. W. Retractor Designed to Facilitate Exposure in Operations on Spinal Column and Other Deep Structures, *Am J Surg* **67** 572 (March) 1945

847 Shelden, C. H., and Pudenz, R. H. Improved Retractor for Hemilaminectomy, *Surgery* **16** 884-885 (Dec) 1944

848 Glaser, M. A. Automatic Self-Retaining Laminectomy Retractor, *J Neurosurg* **2** 285-286 (July) 1945

849 Hoen, T. I. Special Self-Retaining Retractor for Use in Interlaminar Approach to Hernias of Intervertebral Disk, *Ibid.* **2** 459-460 (Sept) 1945

A stainless steel anastomosing tube for use in repair of tendons and nerves has been devised by McKee⁸⁵⁰. The caliber of the tube corresponds with the size of the tendon, and the tube has stamped through it small kick-up spikes, somewhat similar to those employed in woven bandage fasteners, to hold the ends in close apposition when they are pushed into the tubes. These holes help to permit exchange of fluid within and without the tube, make suturing unnecessary and allow immediate activity. The article is well illustrated. Unfortunately, the manufacturer of the tubes is not given.

An instrument similar to a Masson⁸⁵¹ fascial splitter has been devised by Webster⁸⁵² for excising tendons of amputated fingers that are interfering with the function of the remaining finger tendons. This is somewhat different from the Bunnell⁸⁵³ stripper, which allows its application to an intact tendon, both ends of which are attached.

An important fundamental article on the successful transplantation of epiphysial cartilage has been published by Wenger⁸⁵⁴; it exhibits roentgenograms proving the growth of a transplanted proximal end of a fibula employed to replace a destroyed first metatarsal in a boy 7 years old. This disproves the contention of Haas that the epiphysial cartilage plate loses its power of causing bone growth after transplantation. This particular transplant has been growing for four years, and as the patient is still growing, the eventual fate of the transplant is unknown. It is hoped that at bone maturity a final report will be made on this fundamentally important problem.

Of more interest to the oral surgeon than the orthopedic surgeon is the vitallium mandibular prosthesis reported by Winter, Lifton and McQuillan⁸⁵⁵ but comparable in functional importance and almost in size to the vitallium proximal femur reported in 1943 by Moore and Bohlman. Here again is demonstrated the tolerance of tissue to large masses of inert metal prostheses.

850 McKee, G. K. Metal Anastomosis Tubes in Suture, Lancet **1** 650-660 (May 26) 1945

851 Masson, J. C. New Instrument For Securing Fascia Lata for Repair of Hernia, Proc. Staff Meet., Mayo Clin **8** 529-530 (Aug 30) 1933

852 Webster, G. V. Treatment of Tendons in Finger Amputations and Description of New Instrument, Surgery **17** 102-108 (Jan.) 1945

853 Bunnell, S. Repair of Tendons and Description of Two New Instruments, Surg., Gynec & Obst. **26** 103-110, 1918

854 Wenger, H. L. Transplantation of Epiphysial Cartilage, Arch Surg **50** 148-151 (March) 1945

855 Winter, L., Lifton, J. C., and McQuillan, A. S. Embedment of Vitallium Mandibular Prosthesis as Integral Part of Operation for Removal of Adamantinoma, Am J Surg **69** 318-324 (Sept.) 1945

XXIII RESEARCH

Prepared by

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THE REPORTS on orthopedic research and related subjects for 1945 show a preponderance of articles on neuromuscular studies. The outstanding article of the thirty-four reviewed for this section is that of Bowden and Gutmann⁸⁵⁶ on the denervation and reinnervation of human voluntary muscle. This should be read in full by every orthopedic surgeon. The sixteen articles selected for review in this section divide themselves into the following subjects and will be presented in this order: (1) neuromuscular studies, (2) muscles and blood supply, (3) healing fractures, (4) phosphatase and ossification, (5) bone growth and hormones, (6) plastics in bone surgery, and (7) vitamin D and mineralization of bone.

Neuromuscular Studies—Bowden and Gutmann⁸⁵⁶ have made an excellent study of the innervation, denervation and reinnervation of human muscle in material taken from patients with injuries of peripheral nerves. One hundred and forty biopsies of different muscles from 86 cases were examined. The periods of denervation observed ranged from forty-two days to thirty years.

It was found that denervation leads to progressive shrinkage and ultimate destruction of the muscle fibers with the following observations:

(a) Up to three years, no degeneration and no disruption has been found in the muscle fibers. However, shrinkage and increase of connective tissue in part of the muscle may be too advanced to allow recovery after reinnervation. The essential changes during this period are progressive but unequal shrinkage of the muscle fibers, progressive depletion of the sarcoplasm of the end plate and progressive distortion of the pattern of innervation and vascularization.

(b) From three years onward disruptive changes occur. Shrinkage of the muscle fibers is associated with a longitudinal splitting up of their substance into individual myofibrils and with transverse fragmentation. These fragments are found embedded in connective tissue by which they are ultimately replaced. There is no indication of direct metaplasia into collagenous fibers. In the latest stages of denervation, muscle fibers may be represented by tubes filled with pyknotic nuclei and granules of irregular size and distribution or by small round or oval fragments of degenerated muscle tissue. Cross striation of muscle

856 Bowden, R. E. M., and Gutmann, E. Denervation and Re-Innervation of Human Voluntary Muscle, *Brain* 67 273-313 (Dec.) 1944

fibers may remain intact up to the latest stages of denervation but is lost in the small fragments which may show hyaline and vacuolar degeneration of the cytoplasm. Changes in the nuclei lead to pyknosis and ultimately karyorrhexis.

(c) Up to three months after denervation, the pattern of innervation is intact and the individual Schwann tubes can be followed to their end plates. After about three months, the end plates become increasingly difficult to identify and the pattern of innervation is distorted progressively by the proliferating connective tissue.

(d) In the early stages of denervation there is apparently an increase in the permeability of the vessels leading to the formation of perivascular infiltrations. There is a progressive thickening of the walls of the vessels. The pattern of vascularization is distorted by increasing connective tissue formation. The rich anastomotic network of capillaries is reduced. Finally, the vessels may be completely blocked.

(e) In the latest stages of denervation muscle is represented by fat, connective tissue vessels and the larger empty nerve trunks.

(f) The time of denervation is not the only factor determining the degree of atrophy. There are indications that age, stretch, sepsis and other factors play some part in influencing the degree and rate of atrophy.

(g) The changes in the muscle may be reversed to some extent by reinnervation providing that the integrity of the muscle fibers itself is not attacked. Fragmentation is usually found after three years and represents an irreversible change. Up to three years, delay of repair influences progressively the degree of recovery; after three years the possibility of any useful recovery is in question.

Muscle biopsies were found to provide aids to diagnosis, prognosis and treatment in selected cases of peripheral nerve injuries. The criteria used to evaluate these biopsies are (a) the state of the muscle (degree of atrophy), (b) the state of the nerve (degree of reinnervation) and (c) the period of reinnervation (time between biopsy and the expected arrival of nerve fibers). This is calculated on the assumption that the lesion is an axonotmesis. It is then compared with the state of the nerve and muscle found in the biopsy, and a diagnosis can then be made.

The studies showed that different types of lesions in the main nerve trunk give a characteristic pattern of reinnervation in the muscles, the degree of reinnervation depending on the nature and duration of the lesion. It is possible to distinguish between neuropraxia, partial lesions, axonotmesis and a group composed of unsuccessful sutures, traction injuries, etc. When neither empty nor innervated nerve trunks are found, a diagnosis and prognosis can be given based on the state of the muscle.

In the study there is evidence that the rate of outgrowth of the tips of axons in man is not less than 3 mm a day after an axonotmesis.

There has been no evidence that muscle biopsy is a procedure harmful to the patient. A muscle biopsy may be performed using local anesthesia. The main indications for biopsy are (a) to determine the degree of atrophy, extent of fibrosis or presence of vascular changes in a muscle when full clinical examination has failed to give conclusive evidence, (b) to determine the nature of the lesion of the nerve when the history and clinical examination fail to provide all the necessary data, (c) to determine whether a satisfactory, uniform wave of reinnervation is occurring in long-standing high lesions of nerves (the changes of reinnervation of the distal muscles and cutaneous sensory end organs may be assessed by examination of one of the more proximal members of the muscle group), (d) to assist in determining whether exploration, resection and resuture are indicated after a primary or secondary nerve repair, (e) to determine whether delay or return of functional recovery is due to the state of the nerve or muscle or both, and (f) to provide additional confirmation of the necessity for operation when the patient needs reassurance.

The limitations of biopsy are (a) The biopsy specimen may contain no nerve trunks (out of 140 biopsy specimens 7 contained no nerve trunks, 3 contained only perivascular fibers, this represents 7.1 per cent of the total) (b) A biopsy is only a small sample, when the lesion is a partial one an unduly favorable or unfavorable impression may be gained (c) Sufficient time must have elapsed for reinnervation to have occurred, and if the lesion is high it may not be justifiable to wait for biopsy before exploring the nerve.

Finally, the authors concluded that a repair of nerve three years or more after injury is unlikely to be followed by any useful functional recovery of the muscle.

[ED NOTE—This article contains a tremendous volume of important data for every surgeon treating peripheral nerve injuries. The authors state that the growth of nerves is not less than 3 mm a day, most of the teaching is 1 to 2 mm a day. From the authors' observations, certainly three years is a sufficient length of time to wait for the regeneration of a nerve before transplantation of tendon and muscle is to be considered.]

Hines, Melville and Wehrmacher⁸⁵⁷ studied the effect of electrical stimulation on neuromuscular regeneration and muscular atrophy.

The object of the investigation was to determine the over-all effects on neuromuscular regeneration of a regimen of electrical stimulation which had been proved to be effective in delaying denervation atrophy.

857 Hines, H. M., Melville, E. V., and Wehrmacher, W. H. Effect of Electrical Stimulation on Neuro-Muscular Regeneration, Am. J. Physiol. **144** 278-283 (July) 1945.

and to determine the time after denervation during which electrical treatments are most effective

Daily faradic stimulation was effected on the gastrocnemius in an adult albino rat after tibial nerves had been crushed

The results were as follows 1 Daily treatments greatly retarded the loss of weight and strength in muscles prior to their reinnervation (retarded rate of atrophy) 2 Treatments had no effect on the time of onset of functional reinnervation and on normal innervated muscle This observation indicates that electrical stimulation neither hastens nor retards the progress of axon outgrowth and its establishment of functional contacts with denervated muscle 3 Electrical stimulation and the stretching and fatigue resulting therefrom appeared to be without injurious effects on any phase of neuromuscular regeneration 4 When treatments were continued for some time after reinnervation, the differences between the treated nerves and muscles and their untreated contralateral controls were found to be gradually equalized At thirty-five days after denervation there was no difference between the strength of the treated and untreated muscles and only a small difference between the weights of the muscles The experiments in which the electrical treatments were delayed until after the onset of initial reinnervation showed comparatively little benefit from electrical stimulation Thus an evaluation of the effects of electrical stimulation will be prejudiced by the time after denervation at which critical measurements are made

Thus electrical stimulation by retarding muscular atrophy enables the regenerating axons to make functional contacts with larger and stronger muscle fibers

[ED NOTE.—From the results of these experiments, it can be inferred that daily faradic stimulation of muscles following nerve injury may be indicated up to the time of the complete regeneration of the nerve]

Van Harreveld⁸⁵⁸ attempted to explain the hypothesis that after the removal of part of the innervation of a muscle the remaining motor units grow by "adopting" muscle fibers which originally belonged to the denervated motor units

A severe paresis is produced in the quadriceps and sartorius muscles of rabbits by pulling the sixth lumbar nerve out of the cord The small contingent of motor fibers from the fifth lumbar nerve forms the sole remaining motor innervation of these muscles

Forces which developed in the right and left sartorius and quadriceps muscles during stimulation of the fifth lumbar nerve were recorded A few months after the removal of the sixth lumbar nerve on one side, it was found that the force produced on the side operated on was consider-

ably larger than on the control side. This increase in muscular force starts about two weeks after removal of the sixth lumbar nerve. It is considerable during the first few months and has not quite ceased after six months.

No serious or obvious degeneration was usually found in the sartorius two months after removal of the sixth lumbar nerve, even in the instances in which this muscle was innervated originally only to a small extent by the fifth lumbar nerve (as indicated by the small forces developed on the control side during stimulation of the fifth lumbar nerve).

The average surface of the cross section of the muscle fiber in the sartorius on the side operated on was larger than on the control side.

He concluded "the increase in force observed a few months after the partial denervation of the sartorius and quadriceps muscles is due mainly to an adoption by the motor units belonging to the fifth lumbar segment, of muscle fibers innervated originally by L 6. This adoption would be made possible by an increase of the branching of the end ramification of the motor fibers of L 5. It is possible that the increase in thickness of the muscle fibers is an additional factor in the increase of muscle force of the partially denervated muscles."

[ED NOTE.—The thought contained in this paper of the adoption of paralyzed muscle fibers by normal and uninjured nerves certainly suggests that this idea may be the explanation of some of the return of muscular function in infantile paralysis as well as in obstetric paralysis. The importance of these observations is so great that the experiments should be continued and repeated by others.]

Gutmann⁸⁵⁹ attempted a heteroinnervation of muscle with sensory nerve fibers by suturing the sural nerve and the peripheral stump of the peroneal nerve in rabbits. The effects of denervation were not arrested, and the atrophy proceeded even after the sensory nerve had entered the muscle. Stimulation of the sural nerve did not produce contraction.

The sensory nerve cannot make terminal branches or form new end plates. The endings resemble those in skin at first, being netlike. These fail to persist and disappear, and then filaments run between muscle fibers.

He concluded that only motor fibers are responsible for maintenance of "trophic" conditions and that only they are able to arrest and reverse atrophic changes of muscle fibers in rabbits.

[ED NOTE.—The negative results of these experiments are important. It will certainly clear up the subject in the minds of many physicians.

⁸⁵⁹ Gutmann, E. Reinnervation of Muscle by Sensory Nerve Fibers, *J. Anat.* 79 1-8 (Jan.) 1945.

who have thought of the possibility of a sensory nerve functioning as a motor nerve]

Eisenhauer and Key⁸⁶⁰ attempted to determine two things (1) the optimum position of fixation of limbs in order to conserve muscle power and (2) the best method of treatment of muscles paralyzed by loss of nerve supply They developed a method of recording on a kymograph the twitch strength of the gastrocnemius-soleus group of muscles in cats as a criterion of disuse and denervation atrophy

This method was applied to the study of disuse atrophy After normal values were determined, legs were immobilized for six weeks, with the muscle group in stretched, relaxed and neutral positions Stimulation for eight weeks following removal of the cast showed moderate and persistent disuse atrophy in muscles which were stretched, whereas the relaxed and neutral groups showed little consistent effect

Denervated cats also were immobilized in various positions, but the study was unsatisfactory because no definite contraction plateau could be obtained in response to stimulation However, they suggest that denervated muscle atrophies less if left alone than if immobilized They believe that the danger of "stretch paralysis" has been overemphasized By the same reasoning they believe that the nerve should be repaired before the bone is healed when fractures are complicated by peripheral nerve injuries

Riley, McCleary and Johnson,⁸⁶¹ because of the established relationship of choline to fat and protein metabolism, were prompted to study the effect of choline on atrophy of muscle and bone Their conclusions were 1 Daily parenteral administration of choline chloride had no effect on the course of denervation atrophy of rats 2 Following unilateral section of the brachial plexus, the humerus continued to gain in mass, although more slowly than normal 3 The twenty-four hour uptake of radioactive phosphorus by bone ash is the same on the basis of ash weight in normal and atrophic limbs 4 The phosphorus of tracer doses of calcium phosphorylcholine chloride does not enter bone ash preferentially over that of inorganic phosphate

Muscles and Blood Supply—Using bromphenol blue as an indication of effective vascularization of muscular tissue, Clark and Blom-

860 Eisenhauer, J., and Key, J. A. Studies on Muscle Atrophy Method of Recording Power in Situ and Observations on Effect of Position of Immobilization on Atrophy of Disuse and Denervation, *Arch Surg* **51** 154-163 (Oct.) 1945

861 Riley, R. F., McCleary, B., and Johnson, R. E. Denervation Atrophy of Bone and Muscle Examination of Effect of Choline and Some Further Observations on Metabolism of Phosphorylcholine and Deposition of P32 in Bone, *Am J Physiol* **143** 677-686 (May) 1945

field⁸⁶² studied the results of interrupting the blood supply to muscles of rabbits

The efficiency of intramuscular anastomosis varies in different muscles. The tibialis anticus has two main arteries of supply, and ligation of the lower artery leads to devascularization of the distal half of the muscle with necrosis. Partial interruption of intramuscular vascular channels results in localized areas of devascularization.

They found that necrotic areas are rapidly replaced by regenerated muscle fibers leading to partial reconstitution of muscle.

Experimental gunshot wounds of thigh muscles in rabbits were found to give rise to circumscribed patches of devascularized areas extending some distance from the path of the missile. The importance of this observation was mentioned in connection with gunshot wounds in human beings.

In studies on regeneration of muscle, Clark⁸⁶³ found that in the rabbit the lower one half or two thirds of the tibialis anticus can become completely reconstituted after undergoing ischemic necrosis.

He believes that regeneration is formed entirely as outgrowths of preexisting muscle fibers and not by differentiation of generalized connective tissue cells.

[ED NOTE.—The thought expressed in this article as well as the preceding one that muscle fibers regenerate themselves as outgrowths of preexisting muscle fibers is contrary to present teaching. It is generally accepted that in higher vertebrates new striated muscle cells cannot be formed by the division of preexisting muscle cells and that they cannot be formed from other types of cells such as fibroblasts.]

Blomfield⁸⁶⁴ injected radio-opaque substances into the main limb vessels of a cadaver. Individual muscles and groups of muscles were then dissected out, removed and examined roentgenologically. Five types of vascular patterns were recognized: (1) a longitudinal anastomotic chain formed by a succession of separated nutrient vessels entering muscle throughout most of its length (soleus and peroneus longus), (2) a longitudinal pattern of vessels derived from a common stem and entering one end of the muscle (gastrocnemius) (one would expect this to be unusually susceptible to vascular damage), (3) a

862 Clark, W E L, and Blomfield, L B. Efficiency of Intramuscular Anastomoses, with Observations on Regeneration of Devascularized Muscle, *J Anat* **79** 15-32 (Jan) 1945

863 Clark, W E L. Regeneration of Mammalian Striated Muscle, *Nature* London **156** 109 (July 28) 1945

864 Blomfield, L B. Intramuscular Vascular Patterns in Man Proc Roy Soc Med **38** 617-618 (Sept) 1945

radiating pattern of collaterals arising from a single vessel entering the middle of the muscle (biceps), (4) a series of anastomotic loops throughout the length of the muscle and derived from a succession of entering vessels (tibialis anticus, extensor hallucis longus and long flexors of the leg), and (5) an open quadrilateral pattern with sparse anastomotic connections (extensor hallucis longus)

A survey of the relative vulnerability of muscles to necrosis and clostridial infections as related to vascular pattern is being made. A preliminary survey is mentioned, and the final survey is forthcoming.

[ED NOTE.—The observations in this article certainly are most important and should aid in the determining of the extent of infection as well as necrosis after injury when muscles are involved. This should be especially true of infection and necrosis in the gastrocnemius muscle.]

Healing Fractures—Marshak and Byron⁸⁶⁵ present a method of studying the uptake of radiophosphorus and radiostrontium (radioactive tracers) in the healing of uniform bone lesions of rats *in vivo*.

They used radioactive isotopes of strontium (Sr89) and phosphorus (P32) to study the metabolism of these elements in healing bone. Radiostrontium was used instead of radiocalcium because it behaves similarly but is more convenient technically. Uniform lesions were made in the tibia of a rat. Twenty-four hours before measurements were made, the animals were given the radioactive solution (radiophosphorus as sodium acid phosphate or radiostrontium as strontium chloride) intraperitoneally. Both give off beta particles of the same energy value, and the radiations were measured by a Geiger-Müller counter. The counter was shielded by a lead plate with an aperture 2 by 5 mm so as to register beta particles from the wound only. The counter was checked against a known standard of uranium oxide each day before use.

The results were. In young animals, the latent period for an increased uptake of phosphorus is shorter than in older animals (two compared with four days). The maximum uptake of phosphorus and strontium occurs on the eighth to tenth day in young rats, as compared with a maximum of fifteen days reached in old rats. This parallels the gross healing of the old and young bones. By comparing the ratio of uptake of strontium and phosphorus, it is seen that this ratio tends to increase later in the healing process (more phosphorus and less strontium is taken up in the early stages of healing, as compared with the later stages), it may be possible to utilize this tendency to differentiate between the proliferating and the calcifying stages of bone healing.

865 Marshak, A., and Byron, R. L., Jr. Method for Studying Healing of Bone, *J. Bone & Joint Surg.* 27: 95-104 (Jan.) 1945.

Copp and Greenberg⁸⁶⁶ report studies on rats in which the fibula was fractured Twenty-four hours before killing they gave radioactive strontium and then measured areas with the Geiger-Müller counter The calcification activity was determined by the uptake of radioactive strontium by callus and compared with the opposite normal fibula

The results were as follows

In normal rats most active calcification was in eight to sixteen days The broken bone attains the strength of the opposite in twelve to sixteen days In vitamin A-deficient rats the callus was smaller and calcified rats no significant calcification of callus was noted until vitamin D was added With rats given toxic doses of vitamin D the callus was small and the calcification activity was reduced fication was less active with a delay in healing of the fracture Large doses of vitamin A gave the same results as in normal rats In rachitic

[ED NOTE—The results of these experiments confirm some of our present day concepts of vitamin deficiency and bone healing]

Brush⁸⁶⁷ gave a series of rats 0.33 mg of thyroxin and 0.33 mg of diethylstilbestrol three times weekly intramuscularly

Her conclusions were 1 Neither affects the healing process of fractured fibulas, except possibly by slight retardation, from diethylstilbestrol more than from thyroxin This is probably nonspecific 2 Thyroxin accelerates proliferation, differentiation and resorption of cartilage and bone at the tibial epiphysis The width of the cartilage disk is reduced, and the number and size of trabeculae below the plate decreased The matrix undergoes calcification and regressive changes indicative of aging Longitudinal growth remains normal 3 Diethylstilbestrol inhibits the proliferation and resorption of cartilage and bone at the tibial epiphysis The subepiphyseal trabeculae are abnormally long and heavy and often contain heavy strands of calcified cartilage which have failed to undergo resorption The animals are stunted in growth This is similar to the effects described by other authors employing natural estrogens

Phosphatase and Ossification—Studies on horse and sheep embryos regarding the role of phosphatase in ossification of embryonic bone, performed by Roche and Mourgue,⁸⁶⁸ led to the conclusion that the role of phosphatase is not to favor precipitation of tricalcium phosphate by the mechanism described by Robison but to permit accumulation of

866 Copp, D. H., and Greenberg, D. M. Studies on Bone Fracture Healing Effect of Vitamins A and D, *J. Nutrition* **29** 261-267 (April) 1945

867 Brush, H. V. Effects of Thyroxin and Stilbestrol on Healing of Fractures in Rat, *Am. J. Anat.* **76** 339-373 (May) 1945

868 Roche, J., and Mourgue, M. Premières étapes de l'ossification dans les os embrvonnaires et rôle de la phosphatase, *Compt rend Acad d sc.* **214** 809, 1942

phosphoric radicals in the prebony substance, which independently fixes calcium. The formation of tricalcium phosphate then takes place only after this first phase of ossification is completed. The results also suggest that one of the chief functions of the osteoblasts is the secretion of enzymes (proteases and phosphatase) participating in formation of bone.

Bone Growth and Hormones.—Estrogen and a hormone produced by the anterior lobe of the hypophysis accelerate skeletal aging in growing animals. However, the two hormones accomplish this effect in different ways. The anterior hypophysial hormone stimulates growth and hastens epiphysiodiaphysial union by inducing premature regression and resorption of the epiphyseal cartilage, estrogen, on the other hand, inhibits growth and resorption, thus delaying epiphysiodiaphysial union. In view of these contrasting mechanisms, M and R Silberberg⁸⁶⁹ thought it of interest to investigate the combined effects of these two hormones on skeletal development and aging. Thirty-two virgin female mice 5 to 6 weeks old were given the combined substances. Two types of controls were used, (1) untreated mice and (2) those given only one of the hormones. Results were as follows. Histologic study of the lower part of the femur and upper part of the tibia was performed. In growing mice the skeletal effects of estrogen can be modified by the simultaneous administration of an extract of the anterior lobe of the hypophysis. The two hormones oppose each other in their action on the growth of cartilage, but they cooperate in accelerating the age changes in the latter and in the overproduction of bone—anterior hypophysial hormone by stimulating osteoblastic bone formation and estrogen by promoting hyalinization of the marrow and by inhibiting the resorption of bone. (The changes in the bone represent a combination effect involving two different mechanisms. The anterior hypophysial extract stimulated osteoblastic bone formation, the simultaneously injected estrogen diminished the osteoblastic activity. But this decrease in active formation of bone was more than compensated for by the lag of resorption of the primary spicules.) Thus, the two hormones do not neutralize each other but each tends to exert its own effect on the receptor tissue. The skeletal effects of estrogen are direct ones and are not mediated by the anterior lobe of the hypophysis.

Plastics in Bone Surgery.—Blum⁸⁷⁰ performed a series of experiments on animals in which he inserted absorbable protein plastics and

869 Silberberg, M., and Silberberg, R. Combined Effects of Estrogen and Anterior Hypophysial Extract on Skeleton of Growing Mouse, *Arch Path* **39**: 381-387 (June) 1945.

870 Blum, G. Experimental Observations of Use of Absorbable and Non-Absorbable Plastics in Bone Surgery, *Proc Roy Soc Med* **38**: 169-171 (Feb.) 1945.

nonabsorbable, nonprotein plastics in bone and soft tissue These were machined into plates, screws, nails, etc

The protein plastics were made of (1) casein, (2) fibrin, (3) casein with plasma, (4) casein with red blood cells and (5) casein with whole blood, formalized by emersion in 4 per cent formaldehyde These plastics had less strength than metals but about the same strength as bone They were found to be completely absorbed in soft tissue and bone, had no harmful effects on the tissues and when inserted into bone were replaced by bone The rate of absorption of the plastics depended on the degree of formalization, the size of the implant and the tissue into which the plastic was implanted

The following nonprotein plastics were implanted into the same tissues (1) methyl methacrylate, (2) cellulose acetate, (3) nylon, (4) urea formaldehyde and (5) phenol formaldehyde These plastics were found to have no outstanding advantages over metals The disadvantage was that they were not so strong as metals Many of these nonprotein plastics destroyed embryonic tissue cultures, which would certainly be another disadvantage to their use Methyl methacrylate was one of the nonprotein plastics which did not destroy embryonic tissue cultures

[ED NOTE.—These observations appear to be of great value to those considering the use of plastics in bone surgery The fact that embryonic tissue cultures are destroyed by some nonprotein plastics should emphasize the need for careful study before using this type of plastic in the human body]

Vitamin D and the Mineralization of Bone —Greenberg⁸⁷¹ reports a series of experiments on rachitic rats to determine the effect of vitamin D He has conclusively shown that vitamin D exerts a direct effect on the mineralization of bone in these rachitic animals as well as promoting the absorption of calcium from the digestive tract

Young weaned rats were fed rachitogenic diet (Steenbock-Black) for fifteen to twenty days At the end of this period all the rats had become rachitic Some of these rachitic rats were now given vitamin D in the form of irradiated ergosterol seventy-two hours before the administration of radioactive calcium (Ca45) and radioactive strontium (Sr89) The control rachitic rats were not given the irradiated ergosterol before the administration of the radioactive substances

The results showed that the excreta and skeleton contained the bulk of the radioactive substances, the amount in the soft tissue being

871 Greenberg, D M Studies in Mineral Metabolism with Aid of Artificial Radioactive Isotopes Tracer Experiments with Radioactive Calcium and Strontium on Mechanism of Vitamin D Action in Rachitic Rats, J Biol Chem 157 99-104 (Jan) 1945

negligible. In the rats treated with vitamin D about 15 per cent of the radioactive calcium and 30 per cent of the radioactive strontium passed through the intestinal tract unabsorbed, while in the nontreated group 40 per cent of the calcium and 45 per cent of the strontium passed through unabsorbed. The bones of the rats treated with vitamin D retained a larger proportion of the calcium and strontium than the bones of the rats not treated with vitamin D. Furthermore, the rats recovering from the effects of rickets accumulated nearly twice as much radioactive calcium and strontium per gram of dry bone and one and one-half times as much radioactive calcium and strontium per gram of bone ash as did the rats not recovering from rickets.

[ED NOTE.—From these observations, it appears that in diseases and other conditions showing atrophy of bone vitamin D therapy may be indicated if it is desirable either to increase the mineralization or to prevent the demineralization of bone.]

PREFACE

IN THE preparation of this review of orthopedic surgery for 1945 the titles of 1,325 articles of orthopedic interest were selected from the *Quarterly Cumulative Index Medicus* for 1945

The number of articles reviewed and presented in this year's "Progress" is approximately 890 This is a larger number of articles than that selected for 1944 The increase in the number of articles over 1944 is thought to be due to the number of reports from the general hospitals of the armed services and adequate time for study and writing since the return to civilian practice of those men discharged from the armed services As in the past, each editor has selected the articles for his section which he thinks represent the most progress and have the greatest scientific interest The chairman of the editorial board has reviewed the material prepared for each section and has made certain additions and changes which seemed indicated to standardize the publications

Because of the delay of the publishing of the *Cumulative Index Medicus* for 1945, the reviews have been slow in being returned to the chairman of the editorial board and, as was true in the past three years, it was found impossible to send the whole "Progress" to the ARCHIVES at one time This has necessitated a slight change in the order of publication of the sections The preface could not be written until all sections had been submitted In spite of the difficulties encountered in getting reprints, it is hoped that the quality of the reviews is up to standard and that the publication will prove as valuable to its readers as the "Progress" of previous years

The members of the editorial board wish to thank again those physicians not members of the American Academy of Orthopaedic Surgeons who have rendered such valuable assistance in the preparation of the material for the various sections

Special thanks are rendered to Dr J A Toomey, of Cleveland, for editing the research portion of the section on "Poliomyelitis" and to Dr Robert L Bennett, of Warm Springs, Ga, for editing the physical therapy portion of the section on "Poliomyelitis"

The following physicians acted as assistants to members of the editorial board

Dr Ghormley Dr Mark B Coventry, Dr Cameron Allen, Dr Robert B Elliott, Dr Alfred E Jackson, Dr Einer W Johnson, Dr Jack Paschall and Dr Arnulf R Pils

Dr Hauser Dr Robert P Montgomery

Dr Meyerding Dr Arnulf R Pils, Dr Jack Paschall, Dr Einer W Johnson, Dr Alfred E Jackson, Dr Robert B Elliott and Dr Cameron Allen

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Dr White and Dr Frankel Dr Bruce J Brewer and Dr John W Baluss

Dr Alan DeForrest Smith Dr L Miller, Dr Strassburger, Dr J Miller, Dr Ralston, Dr Blunden, Dr Knocks, Dr Hollins, Dr Garber, Dr Bush and Dr Earp

Both style and editorial comments have again been left to the discretion of the editors except for a few changes made by the chairman. It should be stated again, however, as in the preface of the "Progress" of previous years "If the reader or author of any article does not agree with the editorial comment, the editorial board hopes that he will think of the remark as only one man's impression and as in no way representing the opinion of the entire editorial board or of the American Academy of Orthopaedic Surgeons

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By invitation J A Toomey, M.D, and Robert L Bennett, M.D

upper region of the abdomen, which suggests the presence of disease of the gallbladder, renal ptosis or intestinal obstruction and tends to mask the true condition.

In the progressive case the loss of appetite and the pernicious vomiting result in extreme dehydration, emaciation, gradual exhaustion and death.

The presence of duodenal regurgitation should be suspected when a history is obtained of repeated attacks of nausea and vomiting, which are not explainable by the ordinary causes suggestive of an organic lesion in the abdomen.

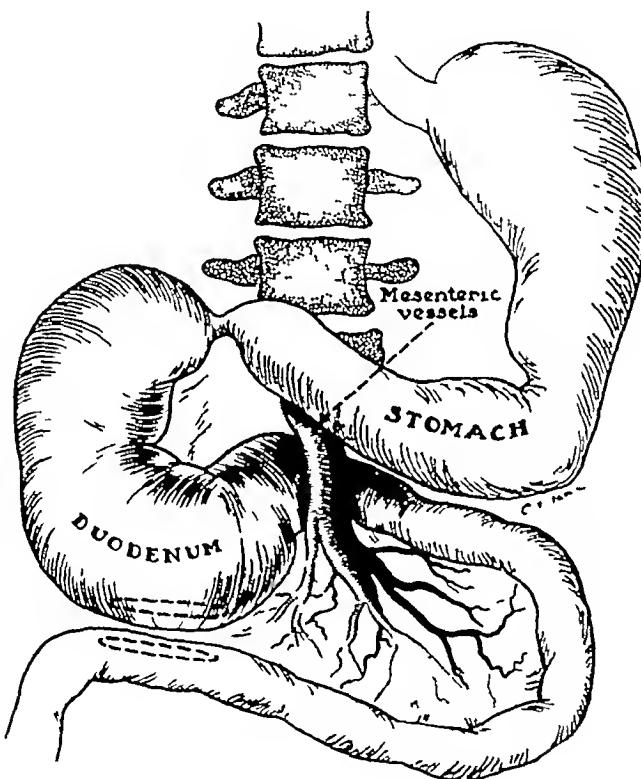


Fig. 1.—Dilated duodenum due to pressure of the mesentery where it passes over the spine.

A positive diagnosis is made by a careful fluoroscopic examination. The stomach is usually large and of the low vertical J-shaped type with a highly placed outlet. The duodenum is dilated to several times its normal size. The barium meal will be observed to stop to the right of the spine and churn back and forth because of hyperperistalsis and then to regurgitate back into the stomach. After a delay of five to ten minutes, the barium may be forced over the spine and may move along in a normal manner. The size of the duodenum will depend on the duration and degree of obstruction.

In the differential diagnosis the condition will have to be distinguished from disease of the gallbladder, cysts or tumors of the duodenum, anomalies producing kinks or bands resulting in obstruction and ptosis of the right kidney.

The treatment depends on the degree of obstruction present. When it is slight and the symptoms come and go, careful medical management consisting in regulation of the intake of food and rest at mealtime may

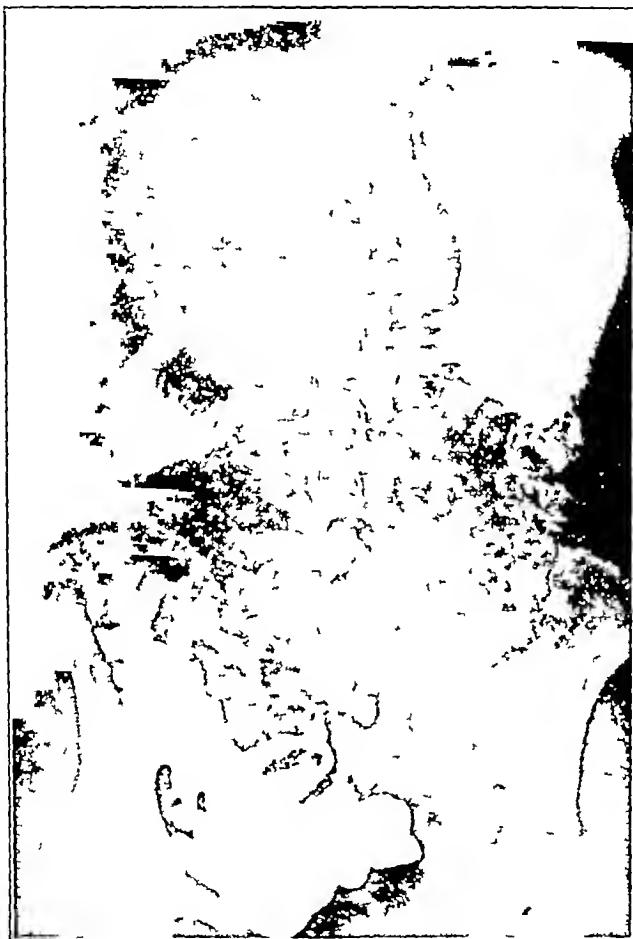


Fig 2.—Roentgenogram showing typical dilated duodenum

give the desired results. The object is to increase the weight of the patient so as to increase the fat in the abdomen with the hope that pressure on the duodenum will be reduced.

When the symptoms of fulness, nausea and vomiting are persistent, the patient should be given rest in bed and frequent small feedings of nourishing foods. Various positions should be tried during and after meals with the hope of relieving pressure and aiding in the passage of

food over the spine. Lying on the left side or on the abdomen may give relief. The knee-chest position may also be tried and in some cases has given good results.

If the patient does not make satisfactory progress in one to two months of careful medical management, surgical treatment is indicated.

The accepted surgical treatment is a duodenojejunostomy. This operation when properly performed will give complete relief. In making the enteroenterostomy, care should be taken to make the opening large



Fig. 3.—Roentgenogram showing marked obstruction at the spine in oblique view.

enough so as to enable prompt emptying of the distended duodenum. The duodenum to the right of the spine is located retroperitoneally, which means that it is placed deep in the abdomen and requires extra dissection to mobilize it enough so that an enterostomy can be done. If the loop is long the operation is easily performed, but if it is short, it becomes a more difficult procedure.

Another surgical operation which can be performed consists in posterior gastroenterostomy accompanied with occlusion of the pylorus.

The latter may be accomplished by tying a heavy silk or cotton tape about the outlet, making it tight enough to obstruct the lumen but not to produce a necrosis.

In a series of 15 patients, 10 were relieved by gastroenterostomy and ligature about the pylorus and 5 by duodenojejunostomy.

My first positive diagnosis of duodenal regurgitation was made in 1928 for a boy 14 years old who in four months lost half of his weight, which decreased from 120 (54 Kg) to 60 pounds (27 Kg). He had been observed in two other hospitals for one month and dismissed



Fig. 4.—Roentgenogram showing prompt emptying of the duodenum following large duodenojejunostomy.

as having hysterical vomiting which was probably used as an excuse for not going to school. The patient complained of pain in the right upper area of the abdomen when attempting to eat, which was immediately followed by vomiting. Examination under the fluoroscope showed a distended duodenum, with large peristaltic waves and regurgitation into the stomach. It was evident that it was necessary to get the food into the intestines to the left of the spine. He was not responding to rest in bed with frequent small feedings.

The patient had become so dehydrated and emaciated that it was decided to do the easiest surgical operation possible to short circuit the duodenum. This consisted of doing a gastroenterostomy and producing an occlusion of the pylorus by tying a heavy double silk ligature about the outlet as described previously. After the operation, the patient stopped vomiting, started to eat promptly and regained his normal weight in two months.

He returned to school, went through law school and was admitted to the bar. Reexamination eighteen years later revealed that he never has had any return of his gastrointestinal symptoms and has enjoyed good health. Fluoroscopic examination at this time showed the gastroenterostomy to be functioning satisfactorily. It was also observed that the pylorus was functioning properly, with a normal outlet and duodenal

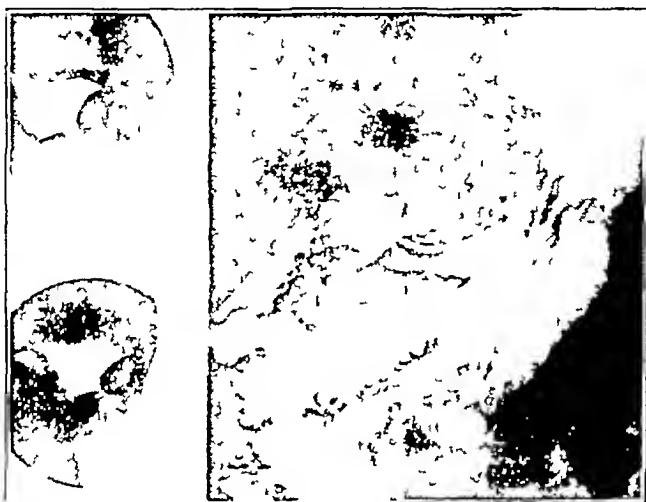


Fig 5.—Roentgenogram of a patient operated on eighteen years previously showing prompt emptying of the stomach through the gastroenterostomy opening and the opening of the pylorus, which had been ligated by heavy silk at the time the gastroenterostomy was performed.

cap and a normal-sized duodenum. There is the question now of what happened to the heavy double silk ligature. It probably sloughed into the bowel and allowed the pylorus to reopen.

A similar surgical procedure was used for 9 other patients, with satisfactory results. On the last 5 a duodenojejunostomy was performed.

The most recent case (1946) of duodenal regurgitation involved a young woman of 25 years of age who lost 30 pounds (13.6 Kg.) in six months. She complained of recurring attacks of abdominal cramps for the past five years which had become so severe six months previously that she had sought relief. Roentgenologic examination at that time showed hyperperistalsis in the duodenum, but it was not looked on as an important finding. She was placed on a nutritious diet after a

tonsillectomy, however, her symptoms continued, consisting of cramps in the right upper area of the abdomen associated with nausea and a rapid loss of appetite soon after she began to eat. Repeated roentgenologic examinations showed a pronounced dilatation of the duodenum with large peristaltic waves and regurgitation into the stomach. An operation was decided on, and a large duodenaljejunostomy was performed. After operation, the patient obtained prompt relief from her former symptoms and continued to make an uneventful recovery. She was able to return to her work after three weeks free from all symptoms and gaining in weight.

Prior to 1928, I observed, along with other clinicians 4 cases during a period of fifteen years. The true condition was probably never recognized, but a lasting impression was left. Two of the patients were young women with pernicious vomiting who after years of medical management gradually became exhausted and died of malnutrition.

The other 2 patients had similar clinical symptoms of nausea and vomiting, but they have survived. One had her gallbladder removed, with no relief, and a gastroenterostomy was done later, but the pylorus was not occluded. She continued to have symptoms of nausea and refused to have further surgical treatment.

Another young woman presented a similar group of symptoms. A small duodenaljejunostomy was done, which did not give complete relief. Later a gastroenterostomy was performed, but she still complained of nausea and occasional vomiting.

These 4 cases impressed me immensely and proved the truth of an often repeated saying of the late Dr Bertram W Sippy—"If our foresight was as good as our hindsight, many things might have been different."

CONCLUSIONS

Duodenal regurgitation should be suspected in recurring attacks of nausea and vomiting associated with loss of weight. The positive diagnosis is made by the radiologist on the observation of a dilated duodenum to the right of the spine, with delay of barium passing over the spine and with hyperperistalsis and regurgitation of barium back into the stomach.

Medical management should first be tried, but if satisfactory results are not obtained in one to two months, surgical treatment should be advised.

The surgical treatment of choice is a duodenaljejunostomy, in which care is taken to make the anastomosis large, of 6 to 8 cm in length, so as to enable prompt emptying of the dilated duodenum.

An alternative surgical procedure may be used consisting of gastroenterostomy and occlusion of the pylorus by ligation with heavy silk or cotton tape.

RELATIONS OF NERVE ROOTS TO ABNORMALITIES OF LUMBAR AND CERVICAL PORTIONS OF THE SPINE

J JAY KEEGAN, MD
OMAHA

THE FINDING of diagnostic areas of sensory reduction, or hypalgesia, with loss of a single nerve root has made possible the accurate identification and location of nerve roots in their relation to vertebral sequence and abnormality. From this study it has been found that each nerve root maintains a constant position in the total series of vertebrae, regardless of a variable number of ribs or of transitional types of vertebrae. This observation is of considerable importance in the interpretation of nerve root syndromes in relation to lesions of the spine, particularly in the localization of posterolateral herniation of an intervertebral disk. It has made unnecessary the use of the spinogram in the great majority of typical cases and has clarified some misinterpretations of anatomic and pathologic variations of the spine not related to symptoms of nerve root involvement. This paper is presented in support of these statements and is based on careful neurologic observations in a large series of clinical cases with surgically verified compression, traction, injection or section of single nerve roots, reported in four previous articles¹. The first paper, on the lower extremity, was published in 1943, and the accumulated material up to recent date is shown in table 1. Of the 1,030 cases of herniation of a lumbar intervertebral disk observed with dermatome hypalgesia, the location of the lesion of the nerve root was verified by operation in 588. The group of cases of lesions of cervical nerve roots, 96 in number (table 2), is not so large, yet the incidence of such lesions has been

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1 Keegan, J J (a) Dermatome Hypalgesia Associated with Herniation of Intervertebral Disk, Arch Neurol & Psychiat **50** 67 (July) 1943, (b) Neurosurgical Interpretation of Dermatome Hypalgesia with Herniation of Lumbar Intervertebral Disc, J Bone & Joint Surg **26** 238 (April) 1944, (c) Diagnosis of Herniation of Lumbar Intervertebral Disks by Neurologic Signs, J A M A **126** 868 (Dec 2) 1944, (d) Dermatome Hypalgesia with Posterolateral Herniation of Lower Cervical Intervertebral Disc, J Neurosurg **4** 115 (March) 1947

sufficiently high during the past two years to indicate the commonness of this syndrome and to give evidence, in 31 verified cases, of the reliability of identification of the nerve root by dermatome hypalgesia

Progress in this field of neurologic diagnosis has been retarded too long by acceptance of the dictum² that loss of a single nerve root produces no loss of sensation, by inability of other investigators to test carefully enough to detect and outline the definite dermatome area of hypalgesia which can be found, and by failure to recognize that discrete postero-lateral herniation of the nucleus pulposus of an intervertebral disk

TABLE 1—*Clinical Cases of Dermatome Hypalgesia in the Lower Extremity Referable to a Single Nerve Root**

Dermatome	No of Cases	Per Cent	Verified by Operation
Third lumbar	14	1.3	5
Fourth lumbar	95	9.2	29
Fifth lumbar	389	37.6	230
First sacral	521	50.6	317
Second sacral	11	1.1	7
Total	1 030	100.0	568

* These data represent cases up to Jan 28, 1947

TABLE 2—*Clinical Cases and Student Injections Showing Dermatome Hypalgesia in the Upper Extremity Referable to a Single Nerve Root**

Dermatome	Cases	Student Injections	Total No	Operation	Localization of Lesion Verified
Third cervical dermatome	7	0	7	1	1
Fourth cervical dermatome	5	1	6	1	2
Fifth cervical dermatome	10	1	11	2	3
Sixth cervical dermatome	15	2	17	7	9
Seventh cervical dermatome	21	1	22	5	6
Eighth cervical dermatome	18	3	21	3	6
First thoracic dermatome	12	2	14	2	4
Total	88	10	98	21	31

* These data represent cases up to Jan 28, 1947

compresses only one nerve root. Degeneration and separation of the nucleus pulposus of the disk, without extensive degeneration of the annulus fibrosus lead to posterior shift of the nucleus within the disk on stooping strain (fig 1), with sudden pain or "catch" in the back and usually with no symptoms referable to the nerve root at this stage. If the nucleus breaks through the posterior longitudinal ligament (fig 2), it usually is to one side of the midline, directly beneath a single nerve root as it leaves the dural canal. Direct observation at operation (fig 3) shows only one nerve root flattened over the herniation tumor in a position which would make compression possible. Nerve roots

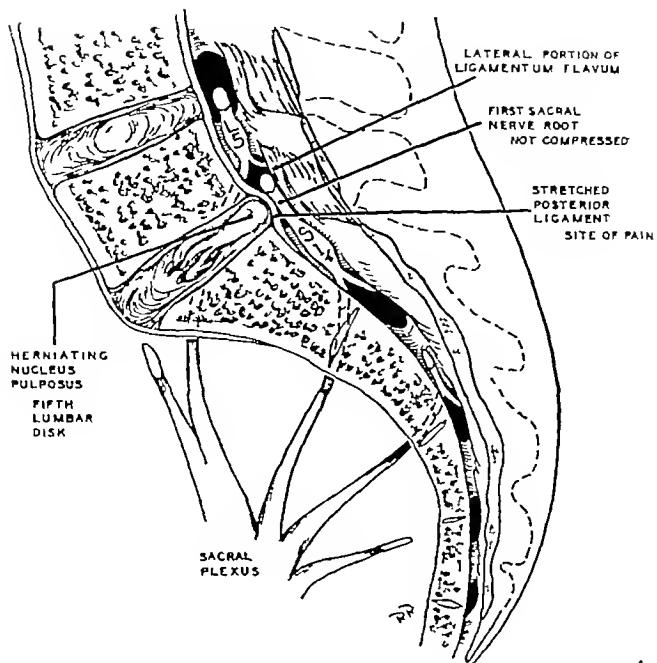


Fig 1.—Sagittal view of herniating nucleus pulposus of the fifth lumbar intervertebral disk. Note position of the first sacral nerve root over the elevation of the posterior longitudinal ligament

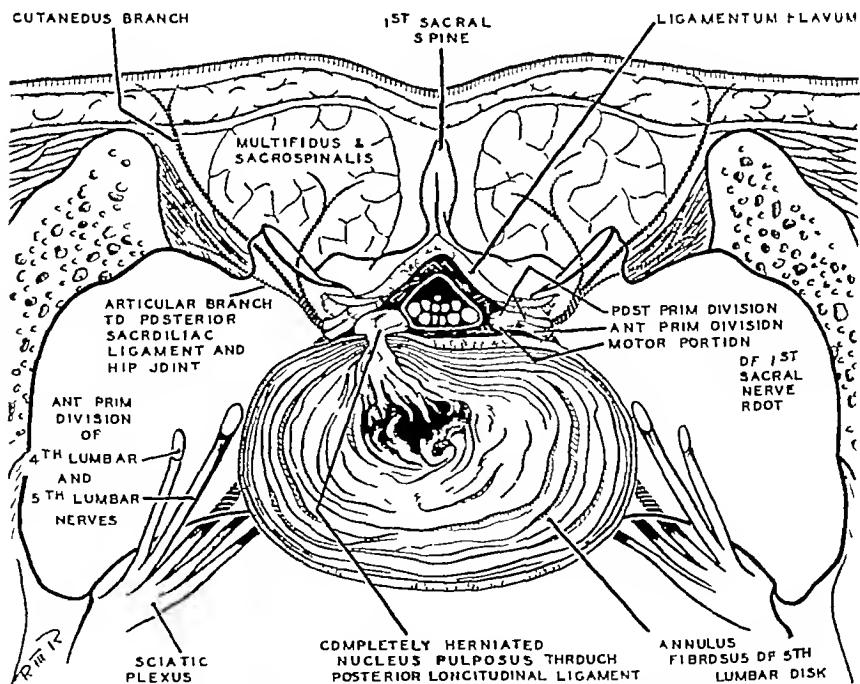


Fig 2.—Transverse view of herniation of the nucleus pulposus of the fifth lumbar disk. (after Keegan^{1b}) Note perforation of the posterior longitudinal ligament and compression of the first sacral nerve root.

of the cauda equina, which are not fixed at the site of the herniation easily move aside unless the herniation is unusually large and fills most of the spinal canal. The nerve root of the corresponding disk emerges from the spinal canal nearly 1 cm above the site of herniation and lies well lateral as it crosses the disk, where herniation of the nucleus does not commonly occur. Further evidence has been obtained repeatedly by traction on a single nerve root at operation, which leads to more evident postoperative dermatome hypalgesia and subjective complaint of numbness in one or more digits supplied by that root.

The method of testing for this sensory loss is quite simple but is evidently difficult for others to apply. All that is required is a light

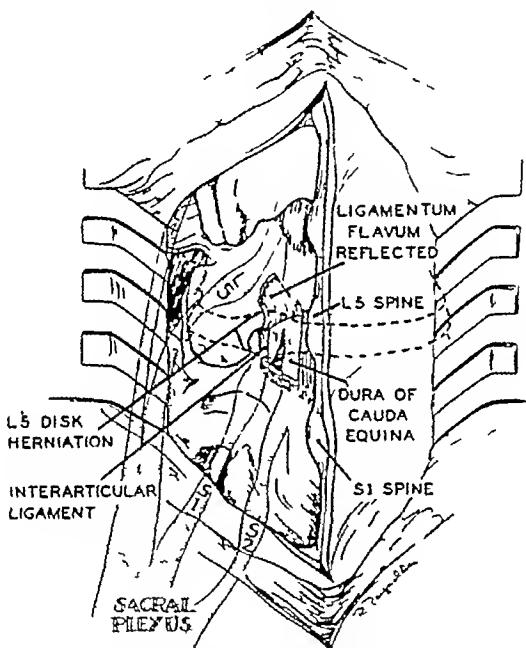


Fig. 3.—Surgical view of herniation of the fifth lumbar intervertebral disk compressing the left first sacral nerve root. Note the anatomic position of the fifth lumbar nerve root at a distance from this herniation.

pin scratch, adjusted so that the patient identifies it as sharp but not painful and reports it as definitely sharper as the pin passes out of the hypalgesic area into the normal zone. Figure 4 shows the dermatome pattern of hypalgesia thus outlined for each nerve root of the lower extremity. With this dermatome chart in mind, a careful history usually will indicate the nerve root involved, by the patient's fairly accurate location of the radiating nerve root pain or of the sensation of numbness in the dermatome distribution. Thus, with compression of the first sacral nerve root he will describe the pain as radiating down the midbuttock and the posterior aspect of the thigh and calf to

the lateral surface of the ankle or foot, often with a sensation of numbness in the little toe. With compression of the fifth lumbar root, the pain will be more lateral in the thigh and calf, radiating to the front of the ankle and foot, with a sensation of numbness in the middle toes, often including the great toe. With compression of the fourth lumbar nerve root, the pain will radiate down the lateral aspect of the buttock.

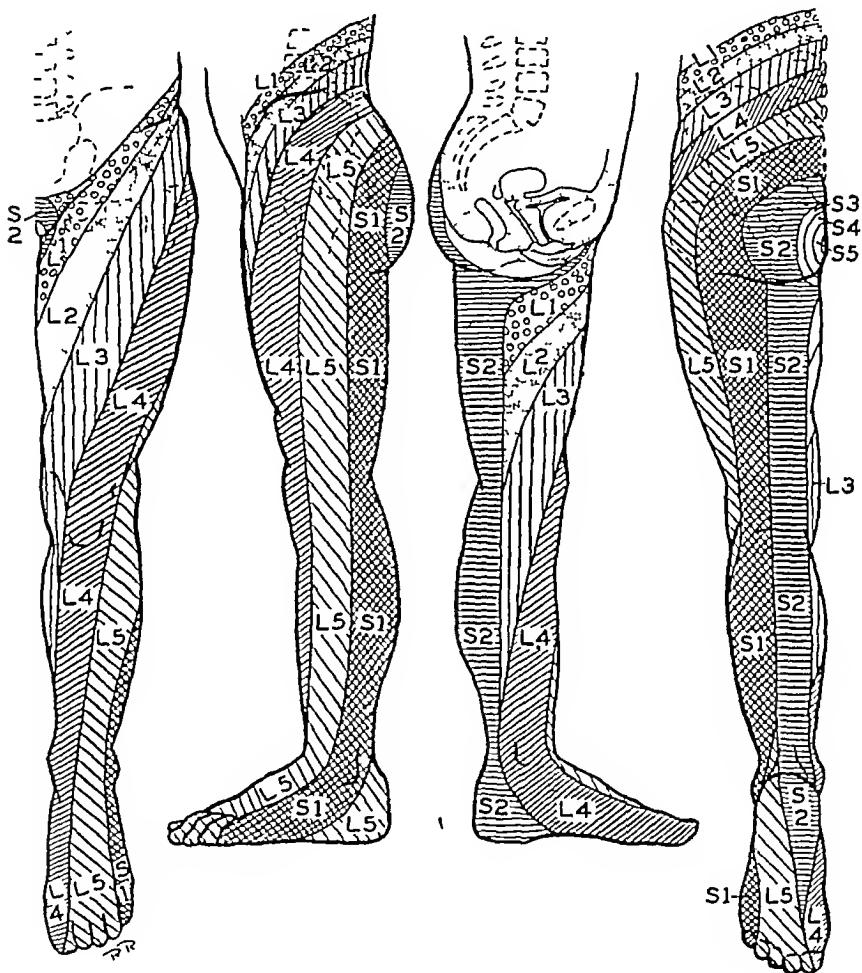


Fig 4.—Dermatome chart of the lower extremity determined by the pattern of hypalgesia from loss of a single nerve root.

and the anterior surface of the thigh, over the knee cap and down the mesial surface of the tibia, also with numbness of the great toe. The dermatome pattern of hypalgesia for the upper extremity is shown in figure 5, and a similar diagnostic implication is possible from the patient's location of radiating pain over the scapula and down the arm, with a sensation of numbness in one or more digits. Thus, with compression of the sixth cervical nerve root the sensation of numbness will

be in the thumb, with compression of the seventh cervical nerve root, in the index and middle fingers, and with compression of the eighth cervical nerve root, in the little and ring fingers. A complete dermatome chart of the human body is presented (fig 6), in which the new dermatome patterns of hypalgesia for the upper and the lower extremities are added to the generally accepted dermatome pattern for the trunk. It should be noted that the dermatome areas in this new chart are arranged in continuous serial order through the extremities, as in the trunk, contrary to the generally accepted anatomic teaching,³ that there

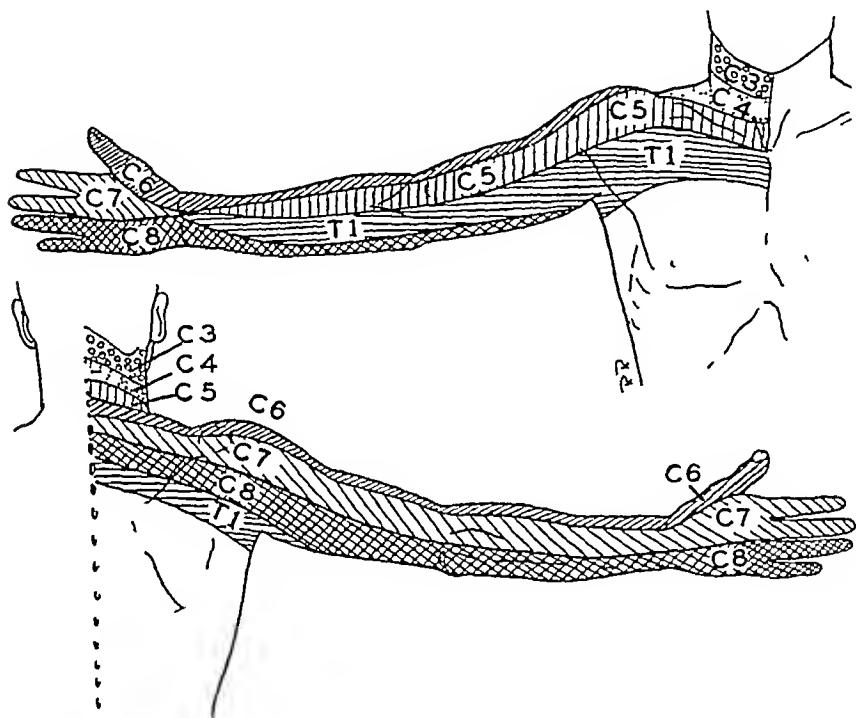


Fig 5.—Dermatome chart of the upper extremity determined by the pattern of hypalgesia from loss of a single nerve root (Keegan,^{1d} page 116)

is an outward migration of dermatomic nerve loops and sensory areas in development of the limb bud

Anatomists also teach that there is great variation in distribution of the nerve roots to the extremities, based on variation in the root composition of the limb plexuses of man and on the reduction of presacral segments or lumbar vertebrae, as in man, particularly as com-

³ Sherrington, C S Experiments in Examination of the Peripheral Distribution of the Fibers of the Posterior Roots of Some Spinal Nerves, Phil Tr Roy Soc., London 184 641, 1893 Bolk, L Die Segmentaldifferenzirung des menschlichen Rumpfes und seiner Extremitäten, Morphol Jahrb 26 91 1898

pared with the number in lower primates and other mammals.⁴ Critical analysis of this concept indicates that it is not well founded (fig 7). The only significant difference between man's five lumbar spinal vertebrae and the rhesus monkey's seven lumbar spinal vertebrae is the fusion of the monkey's sixth and seventh lumbar vertebrae with the sacrum of man, there being only three sacral vertebrae in the monkey. The total number of twenty-nine vertebrae to the end of the sacrum is the same. The error has been in use of the first sacral vertebra.

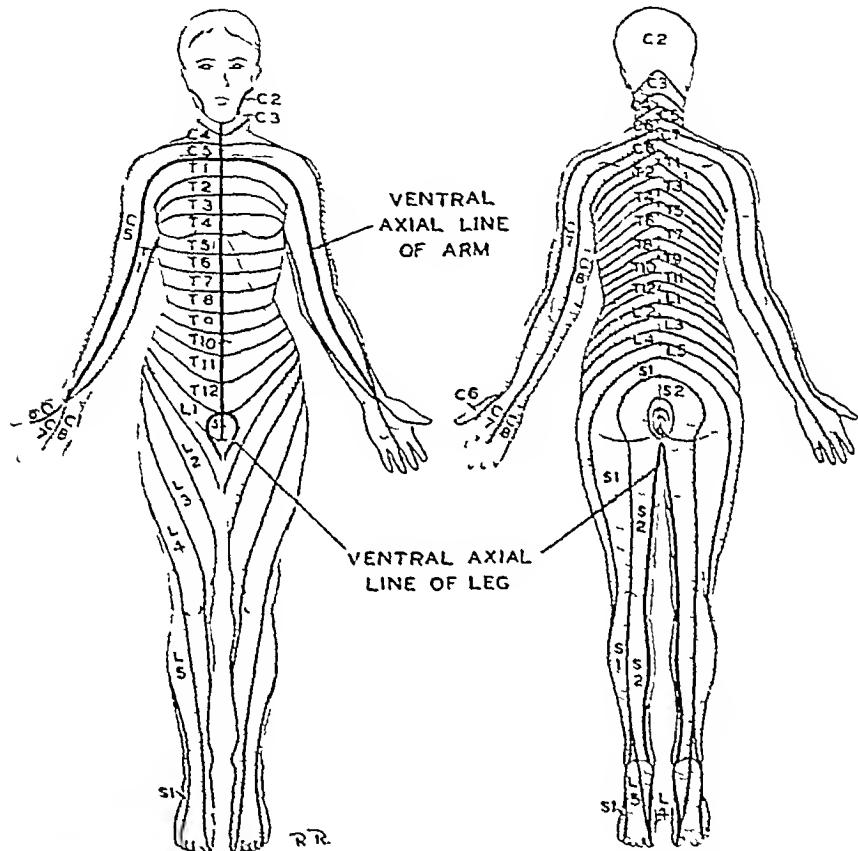


Fig 6.—Dermatome chart of the human body with new dermatome patterns of the extremities combined with standard dermatome patterns of the trunk (Keegan,¹⁰ page 124). Note the serial continuity of the dermatomes in the extremities, as in the trunk.

as an anatomic landmark to identify and compare presacral nerve roots. A more stable primitive vertebra of the sacrum of mammals is the

⁴ Keith, A. The Extent to Which the Posterior Segments of the Body Have Been Transmuted and Suppressed in the Evolution of Man and Allied Primates, *J Anat & Physiol* 37 18, 1902

⁵ Hartman, C G and Straus, W L. *The Anatomy of the Rhesus Monkey*, Baltimore, Williams & Wilkins Company, 1933

twenty-seventh of the total series,⁶ or the third sacral segment of man, with which the lowermost portion of the ilium rather constantly articulates. Fusion of vertebrae above or below this primitive first sacral segment of mammals commonly occurs to meet mechanical needs such as the erect posture of man. This should not be expected to change the peripheral distribution of nerve roots if it is recognized that the first and second sacral nerve roots of man are analogous to the sixth and seventh lumbar roots of the monkey and most lower mammals, or the twenty-fifth and twenty-sixth of the total series (fig. 7).

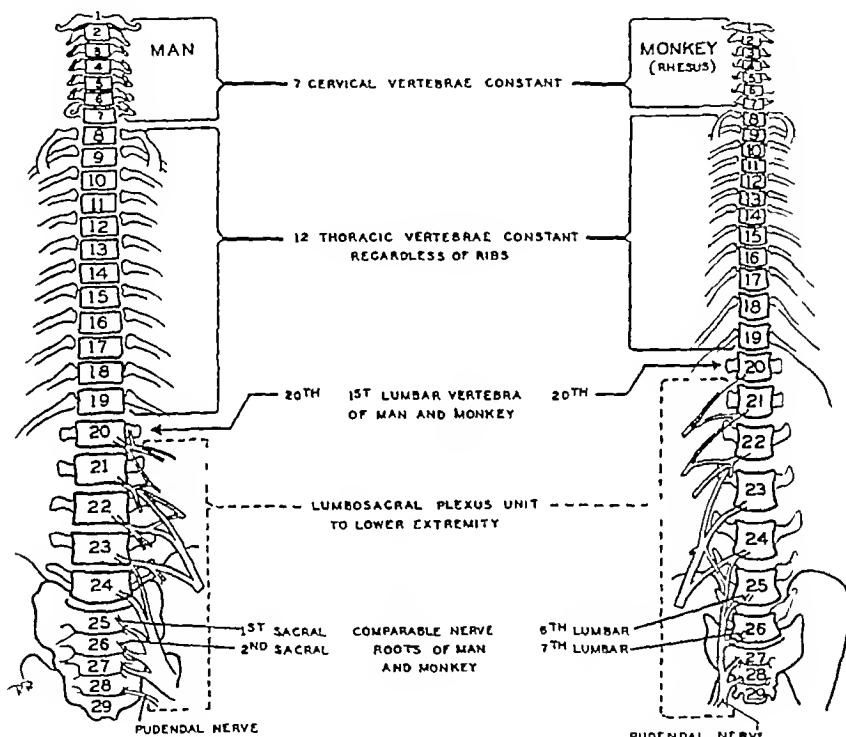


Fig. 7.—Comparison of the spine and lumbosacral nerve roots of the rhesus monkey (modified from Hartman and Straus⁷) with the pattern in that of man. Note the total number of vertebrae are the same and that the numerical relation of the origin of the nerve roots to the sacral plexus is the same.

This study of the cutaneous distribution of nerve roots to the extremities by outlining single nerve root dermatome hypalgesia, with verification by surgical exploration, indicates that there is no change of position of the nerve roots with the addition or reduction of lumbar vertebrae in man if the vertebrae are counted in total numerical sequence, and not by an arbitrary lumbar series defined by the quite variable first sacral segment or last rib. Thus, the commonly identified

⁶ Todd, T. W. Numerical Significance of the Thoracolumbar Vertebrae of the Mammals, *Anat Rec* 24: 261 (Dec.) 1922.

fifth lumbar nerve root, with its characteristic dermatome hypalgesia, has been found constantly emerging from the spinal canal between the twenty-fourth and the twenty-fifth vertebra of the total series, regardless of anatomic variation, and other nerve roots are found in corresponding position in the series

This finding of the constancy of position and cutaneous distribution of the nerve roots in man contradicts the emphasis which previously has been placed on the variable root composition of the sacral plexus and invalidates interpretation of this variation as indicative of segmental evolutionary change. The union of nerve roots to form a plexus is a secondary and fortuitous arrangement to meet limb conformation in different animals. This should not be expected to alter nerve root distribution if all nerve roots to the lower extremity, from the first lumbar to the fourth sacral in man, or the second sacral in the monkey are included, the combined lumbar and sacral plexuses being considered as a unit for the extremity. Thus, variable inclusion of the third or the fourth lumbar nerve root in one or the other plexus is of little significance in ultimate root distribution, likewise, separation of the pudendal nerve in man, derived from the fourth sacral nerve root, in contrast to its inclusion in the sacral plexus of the monkey (fig. 7), does not alter the ultimate distribution of this nerve, as in both cases it is derived from the twenty-eighth nerve root of the total series. While there may be variation of a few fibers in nerve root distribution, as identified by Sherrington,⁷ with the terms prefixed and postfixified plexuses applied, and possibly represented in this study by variable inclusion of the great toe in subjective numbness with involvement of the fifth lumbar nerve root, this is not sufficient to alter significantly the dermatome pattern of hypalgesia for each nerve root.

The somewhat arbitrary division of the spine into cervical, thoracic, lumbar and sacral vertebrae, based on a variable number of ribs and variable fusion of vertebrae with the sacrum, is confusing in the identification of nerve roots. It would be better to identify the vertebrae by serial number, with the corresponding nerve root and disk located immediately below. This would necessitate a special designation for the nerve root which emerges between the skull and the first cervical vertebra as the suboccipital nerve. However, since one is rather firmly committed to the terms cervical, thoracic, lumbar and sacral vertebrae and nerve roots, the number in each group should be defined and limited to a normal of seven cervical, twelve thoracic, five lumbar and five sacral in man, regardless of a variable number of ribs or of transitional vertebrae at the lumbosacral junction. The confusion is

⁷ Sherrington, C S. Notes on the Arrangement of Some Motor Fibers in the Lumbosacral Plexus, J Physiol 13 621, 1892

even greater in identifying a nerve root in relation to herniation of an intervertebral disk. In the lumbar region the herniation compresses the nerve root one segment below the involved disk, not the corresponding nerve root, owing to the obliquity of emerging nerve roots at this level. In the cervical region the nerve roots pass out transversely and are compressed by herniation of the corresponding disk, but, owing to the identification of eight cervical nerve roots and only six true cervical intervertebral disks, the seventh cervical nerve root is observed to be compressed by the fifth cervical disk, and others correspondingly. Consequently, for clarity in describing this syndrome in the cervical region, it is necessary to state that the seventh cervical nerve root is

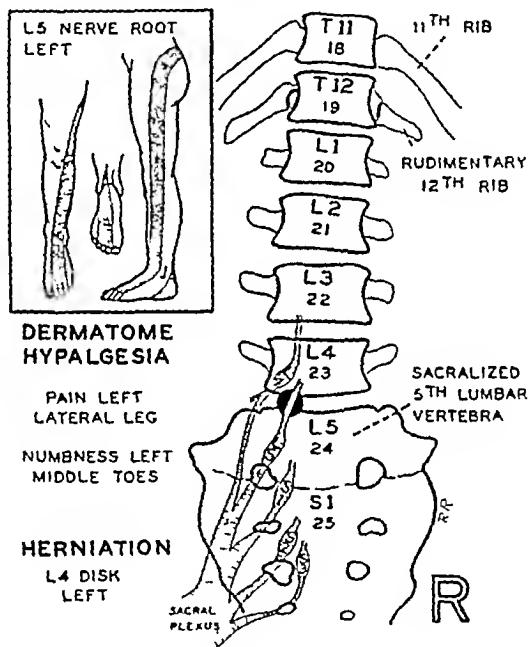


Fig 8 (case 1)—Sacralized fifth lumbar vertebra and rudimentary twelfth rib, determined by total numerical series. Hypalgesia of the left fifth lumbar dermatome localized the herniation on the fourth lumbar disk, between the twenty-third and the twenty-fourth vertebra of the series, with surgical verification.

compressed by the disk between the sixth and the seventh cervical vertebra, and others likewise.

A few clinical cases illustrating the correctness of these anatomic interpretations will be presented, selected from a large number of cases with anatomic variations of the lumbar portion of the spine encountered in association with the syndrome of posterolateral herniation of the nucleus pulposus of an intervertebral disk.

CASE 1 (fig 8)—The patient had only four lumbar vertebrae. The last pair of ribs were rudimentary and were to be differentiated from articulated transverse

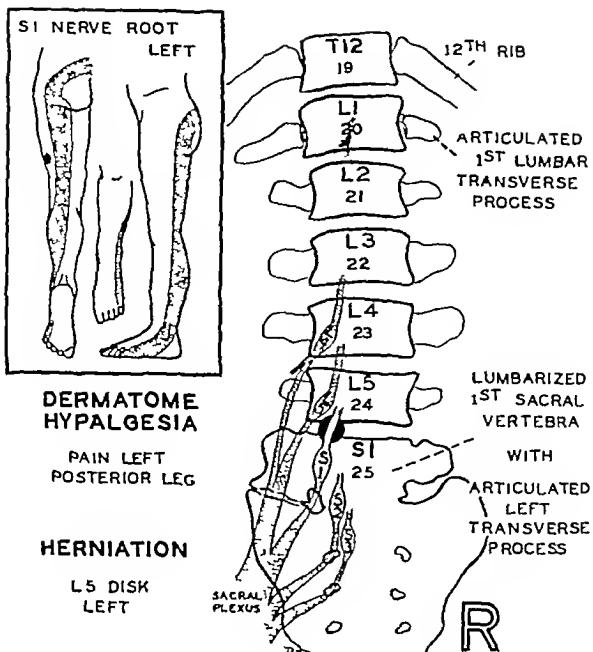


Fig 9 (case 2)—Lumbarized first sacral vertebra and articulated transverse process of the first lumbar vertebra, determined by total numerical series Hypalgesia of the left first sacral dermatome localized the herniation on the fifth lumbar disk, between the twenty-fourth and the twenty-fifth vertebra of the series, with surgical verification

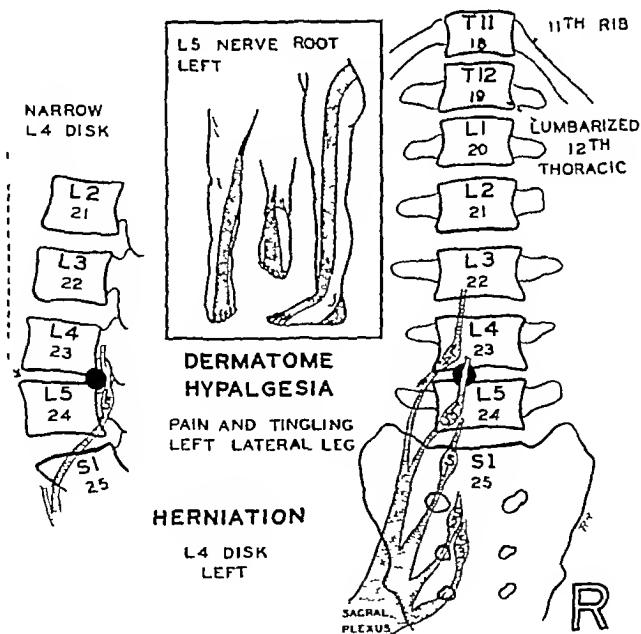


Fig 10 (case 3)—Lumbarized twelfth thoracic vertebra, determined by the total numerical series and count of the ribs Hypalgesia of the left fifth lumbar dermatome localized the herniation on the fourth lumbar disk, between the twenty-third and the twenty-fourth vertebra of the series, with surgical verification

processes of the first lumbar vertebra by roentgenographic count of the number of ribs above. Only eleven ribs were found above these rudimentary ribs, hence, they represented the twelfth pair of ribs and the vertebra was the twelfth thoracic, or the nineteenth of the total series. Five lumbar vertebrae being accepted as normal for man, the fifth lumbar vertebra, or the twenty-fourth of the series, was completely sacralized, it should be recognized as a lumbar vertebra and not called the first sacral vertebra. The dermatome hypalgesia found in this case, with typical symptoms of herniation of the disk, was that of the left fifth lumbar nerve root. Recognizing that this nerve root is constantly compressed by herniation of the disk next above its emergence, or the fourth lumbar disk, and that this disk constantly is found between the twenty-third and the twenty-fourth vertebra of the

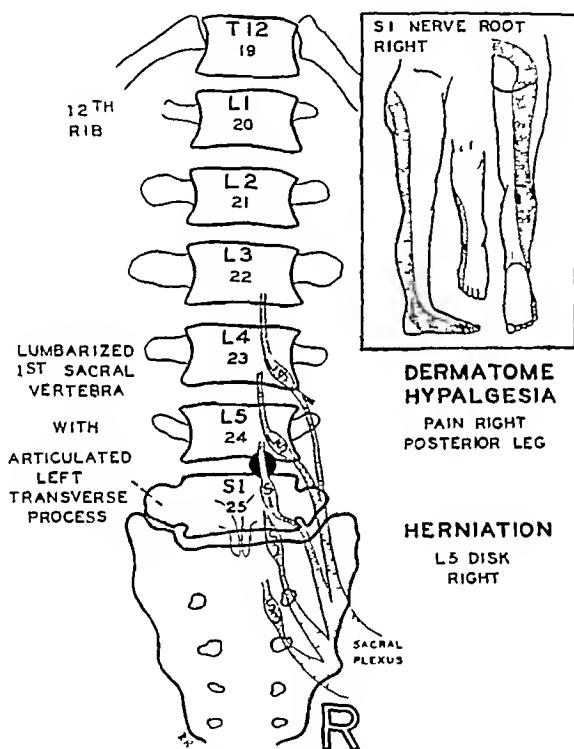


Fig 11 (case 4).—Lumbarized first sacral vertebra, determined by total numerical series. Hypalgesia of the right first sacral dermatome localized the herniation on the fifth lumbar disk, between the twenty-fourth and the twenty-fifth vertebra of the series, with surgical verification.

total series, surgical exploration was directed to this site on the left side and the herniated nucleus pulposus observed, as indicated, over the last disk on this part of the spine.

CASE 2 (fig. 9).—The spine had, similarly, four lumbar vertebrae and what appeared to be rudimentary ribs and a sacralized fifth lumbar vertebra. However, a count of the ribs showed twelve ribs above the rudimentary ones and hence identified the latter as articulated transverse processes of the first lumbar vertebra, or the twentieth of the series, and not the nineteenth as in case 1. A count downward from this vertebra identified the fifth lumbar vertebra as normal and the

transitional vertebra as a lumbarized first sacral vertebra, not a sacralized fifth lumbar, as in case 1. The dermatome hypalgesia found in this case was that of the left first sacral nerve root, which would be compressed by herniation of the fifth lumbar disk, between the twenty-fourth and the twenty-fifth vertebra of the total series. Surgical exploration revealed herniation of the nucleus pulposus as indicated, in the correct serial anatomic position.

CASE 3 (fig 10)—The spine had six normally formed lumbar vertebrae. As the patient was of short stature and unlikely to have an extra vertebra in her spine, a count of the ribs was made by roentgenogram, showing only eleven ribs. Thus, the first free vertebra was identified as the nineteenth of the total series, or the twelfth thoracic, regardless of the absence of ribs. The lumbar sequence then was established and the last lumbar vertebra identified as the fifth lumbar, or

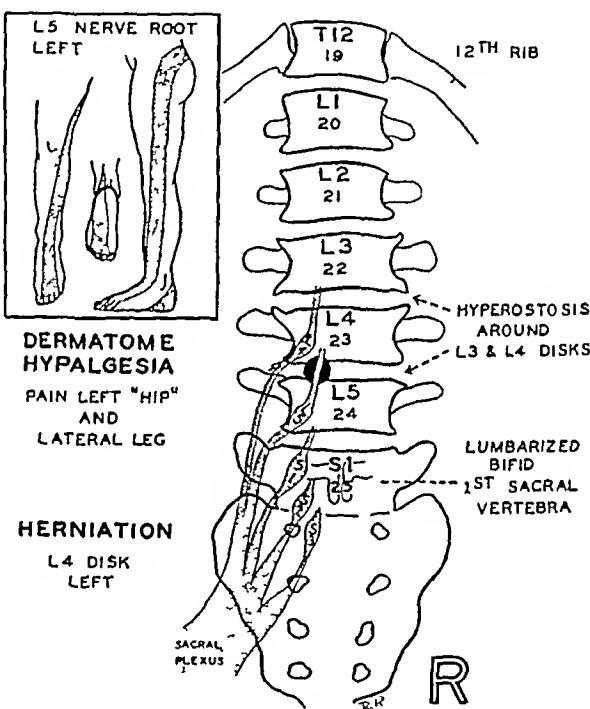


Fig 12 (case 5)—Lumbarized first sacral vertebra, determined by total numerical series. Hypalgesia of the left fifth lumbar dermatome localized the herniation on the fourth lumbar disk, between the twenty-third and the twenty-fourth vertebra of the series, with surgical verification.

twenty-fourth vertebra of the series. The dermatome hypalgesia in this case was that of the left fifth lumbar nerve root, locating the herniation on the left side of the true fourth lumbar disk, between the twenty-third and the twenty-fourth vertebra of the total series, with surgical verification.

CASE 4 (fig 11)—The case was one of hypalgesia of the right first sacral dermatome with a lumbarized first sacral vertebra, locating the causative herniation on the fifth lumbar disk, between the twenty-fourth and the twenty-fifth vertebra of the total series, verified surgically.

CASE 5 (fig 12)—The case was one of hypalgesia of the left fifth lumbar dermatome with lumbarized first sacral vertebra. The causative herniation, of the

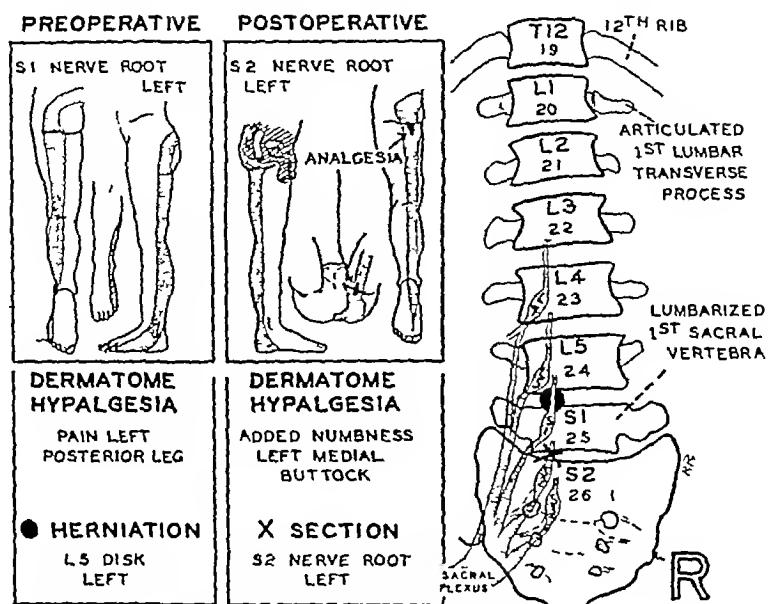


Fig 13 (case 6).—Lumbarized first sacral vertebra, determined by total numerical series. Hypalgesia of the left first sacral dermatome localized the herniation on the fifth lumbar disk, between the twenty-fourth and the twenty-fifth vertebra of the series, with surgical verification. Section of the nerve root crossing the disk between the twenty-fifth and the twenty-sixth vertebra produced characteristic dermatome hypalgesia of the second sacral nerve root.

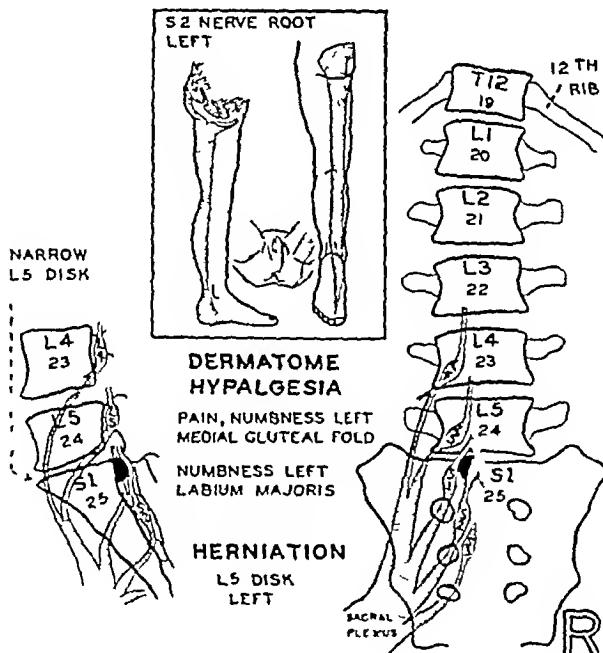


Fig 14 (case 7).—Normal spine with five lumbar vertebrae. Dermatome hypalgesia indicated compression of the left second sacral nerve root. Surgical exploration showed discrete compression of the left second sacral nerve root over a low medial herniation of the fifth lumbar disk. Note anterior extension of hypalgesia to the pubic region.

fourth lumbar disk, was observed between the twenty-third and twenty-fourth vertebrae of the total series.

CASE 6 (fig. 13)—The spine had six lumbar vertebrae, owing to lumbarization of the first sacral vertebra. This was not recognized before operation for herniation of the fifth lumbar disk, which caused pain and hypalgesia of the left first sacral dermatome. Exploration of the last disk of this portion of the spine revealed no herniation. Traction and partial section of the nerve root overlying this disk resulted in added postoperative numbness in the medial gluteal fold, with dermatome hypalgesia, identified as referable to the second sacral nerve root. The herniation causing hypalgesia of the first sacral dermatome was observed on the



Fig. 15 (case 8)—Roentgenogram of the lumbar portion of the spine with spondylosis deformans. Note that the hyperostosed vertebral borders are related to flattened intervertebral disks.

next to the last disk of this portion of the spine, later correctly identified as the fifth lumbar disk, between the twenty-fourth and the twenty-fifth vertebra of the total series.

CASE 7 (fig. 14)—The case was one of a normal spine, with five lumbar vertebrae, with definite hypalgesia of the left second sacral dermatome and a sensation of numbness in the medial gluteal fold and the labium majus on the left side. Surgical exploration showed that the left second sacral nerve root was tightly stretched and flattened over a somewhat medially situated, discrete herniation of the fifth lumbar disk. The first sacral nerve root was displaced laterally but not compressed, and other sacral nerve roots did not appear to be compressed.

Many more cases of anatomic variation in the lumbar portion of the spine with correct localization of a herniated nucleus pulposus by dermatome hypalgesia could be reported, but space does not permit. It should be emphasized that count of the ribs roentgenographically must be made when there is any question of a rudimentary twelfth rib or an articulated transverse process of the first lumbar vertebra or a transitional type of vertebra at the lumbosacral junction to identify correctly the vertebrae and disks in relation to the nerve roots. Although this method of localization of nerve roots in the total vertebral series has been found reliable when a definite dermatome pattern of hypalgesia can be found, it must be recognized that a lesser degree of

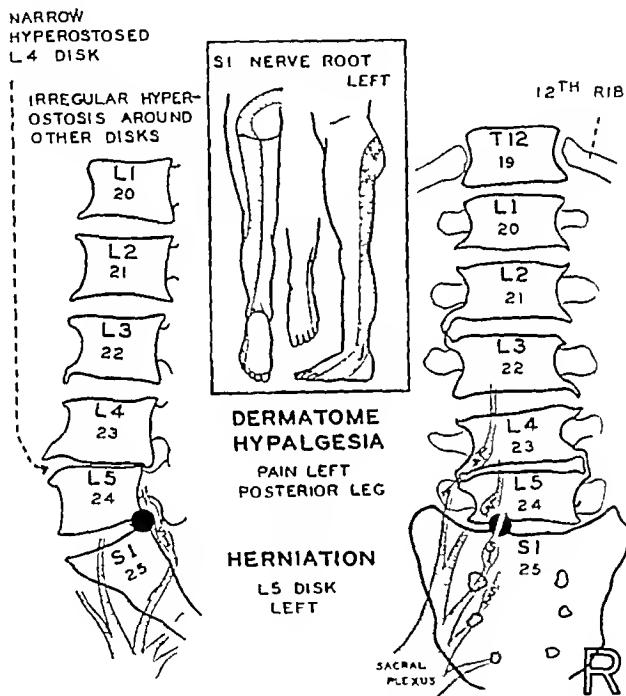


Fig. 16 (case 9)—Lumbar portion of the spine with irregular, hyperostosed vertebral borders surrounding narrowed intervertebral disks particularly the fourth lumbar disk. Hypalgesia of the left first sacral dermatome indicated herniation of the normal-appearing fifth lumbar disk, verified surgically.

or intermittent compression of, the nerve root may not give a definite outline of hypalgesia. In such cases the localization may be misjudged and the wrong disk explored the herniation being usually encountered on the disk next above. However, postoperatively, after traction on the nerve root over the herniation, a definite correct dermatome pattern of hypalgesia for that nerve root with subjective sensation of numbness in the corresponding toes, usually will be found. Another source of seeming error in the method is a more lateral or more

medial herniation than usual, as illustrated by case 7 (fig 14), which may compress a nerve root above or below the usual one over that disk. Or two nerve roots may be compressed by a wide herniation, leading to more extensive hypalgesia and motor loss than usual. Careful analysis must be made in all cases before, at and after operation, to correlate properly symptoms and signs of nerve root involvement with the pathologic process present. A spinogram may occasionally be indicated for further evidence before operation, although, if surgical intervention seems warranted for relief of symptoms, the added exploration of an adjoining disk seems preferable to the possible complications and fallacies of obtaining the spinogram.

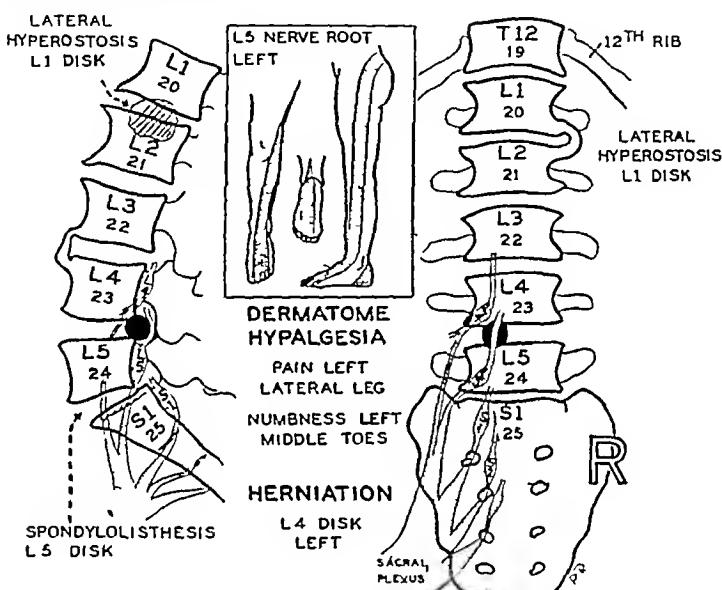


Fig 17 (case 10).—Lumbar portion of the spine with irregular, hyperostosed vertebral borders around the first and third lumbar intervertebral disks and spondylolisthesis of the fifth disk. Hypalgesia of the left fifth lumbar dermatome indicated herniation of the normal-appearing fourth lumbar disk, verified surgically.

There has been considerable disagreement concerning the significance of anatomic and pathologic abnormalities of the lumbar and the cervical portions of the spine in the causation of symptoms. It is not intended to present this subject here, rather, I wish to emphasize that strictly lateralized pain, particularly that which radiates into one buttock, thigh and leg, or over the scapula into the arm, and hypalgesia of single nerve root distribution are symptoms of an organic lesion of a nerve root, and no other interpretation should be given to them. The pain from an anatomic or pathologic abnormality of the spine, to be distinguished from involvement of a nerve root should be located in the midline of the back, and interpretation of the need of spinal fusion be based on pain in the midline of the back, and not on lateralized nerve

root pain Many patients with complete herniation of the nucleus pulposus of a lumbar intervertebral disk volunteer the information that the pain used to be in the back and now is all in one "hip" and leg This indicates a remaining stable annulus fibrosus and spine, the symptoms at this stage being entirely lateralized nerve root pain There would seem to be no indication for spinal fusion in such a case regardless of roentgenographic evidence of abnormalities of the spine

The commonest pathologic abnormality of the lumbar portion of the spine seen in roentgenograms is hyperostosis of borders of vertebrae around a diffusely degenerated and narrowed intervertebral disk, commonly called spondylosis deformans This pathologic process

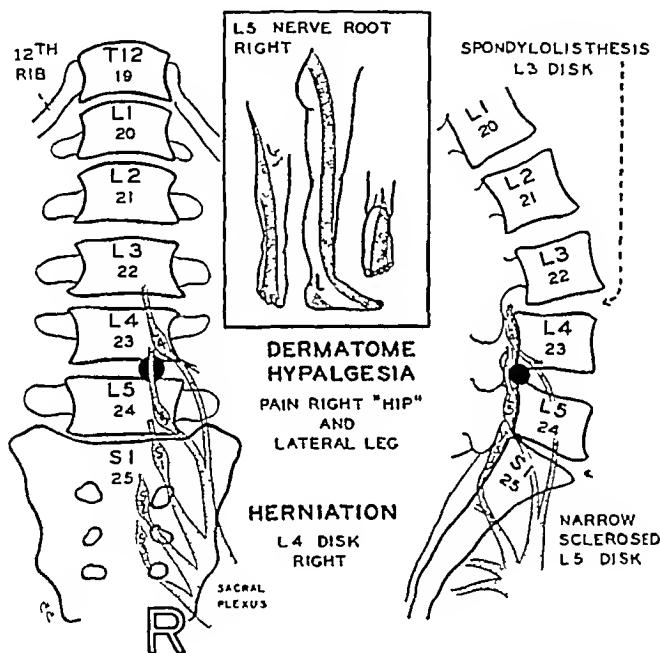


Fig 18 (case 11)—Lumbar portion of the spine with spondylolisthesis of the third disk and narrow, sclerosed fifth disk Hypalgesia of the right fifth lumbar dermatome indicated herniation of the intervening normal-appearing fourth disk, verified surgically

should be described in relation to degenerated disk, caused by protrusion of the disk under compression strain due to heavy work with changes due to bone age in both the disk and the vertebrae Thus diffusely degenerated disk protrudes more anteriorly and laterally than posteriorly, where nerve roots would be compressed, hence seldom gives rise to nerve root pain

CASE 8 (fig 15)—The ease presented a typical hyperostosis of the vertebral borders around degenerated disks, observed incidentally in a pyleogram in a patient without symptoms referable to a nerve root. The patient a man aged 62, gave no history of special trouble with his back except for the usual increasing disability

with age. He had been a stone mason in Minnesota, worked on rolling stones or glacial boulders and stated proudly that in his day he could lift twice as heavy a stone as other men.

CASE 9 (fig 16) —This case presented extensive hyperostosis of vertebral borders, with symptoms of herniation of the nucleus pulposus of the fifth lumbar intervertebral

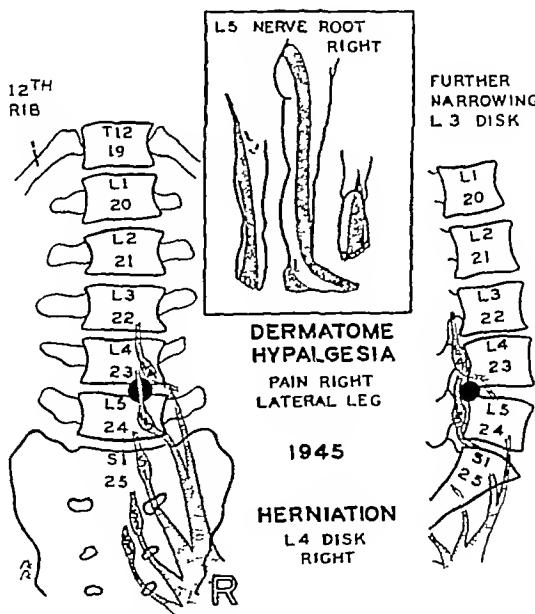
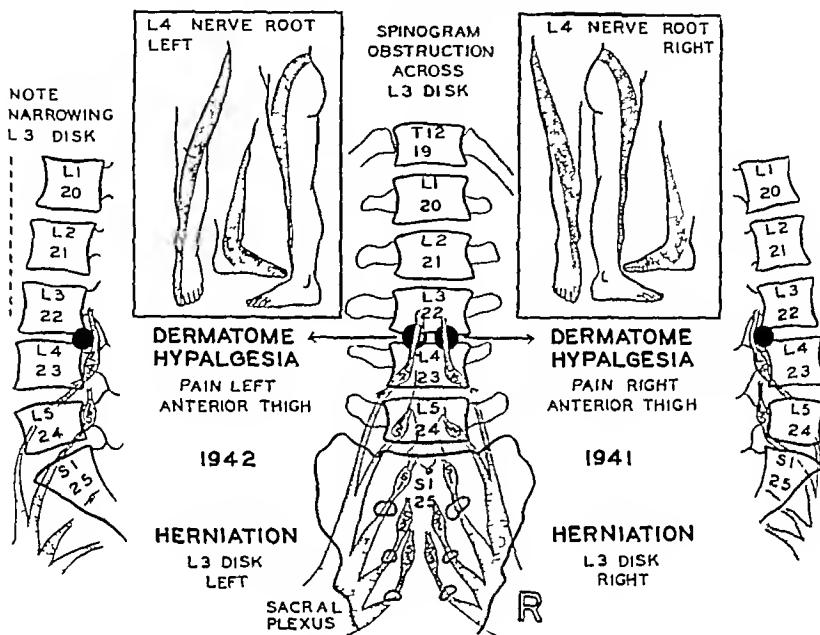


Fig 19 (case 12) —Lumbar portion of the spine, showing progressive narrowing of the third disk with bilateral herniation and hypalgesia of the fourth lumbar dermatome. Later, hypalgesia of the right fifth lumbar dermatome indicated herniation of the fourth lumbar disk, verified surgically.

disk. Of particular interest was the completely obliterated and spontaneously fixed fourth lumbar disk without symptoms of nerve root involvement. The degeneration of this disk had passed the stage of acute herniation of the nucleus which the man presented. Dermatome hypalgesia in the distribution of the left first sacral nerve root placed the herniation on the more normal-appearing fifth lumbar disk, the diagnosis being verified and the condition relieved by operation.

CASE 10 (fig. 17)—The lumbar portion of the spine presented prominent hyperostosis of the upper vertebrae and first degree spondylolisthesis at the fifth lumbar disk. Hypalgesia of the left fifth lumbar dermatome indicated herniation of the nucleus of the normal-appearing fourth lumbar disk, the diagnosis being verified and the condition relieved by operation.

CASE 11 (fig. 18)—The spine showed spondylolisthesis at the third lumbar intervertebral disk and a narrow, sclerosed fifth lumbar disk. The dermatome hypalgesia indicated compression of the right fifth lumbar nerve root by herniation

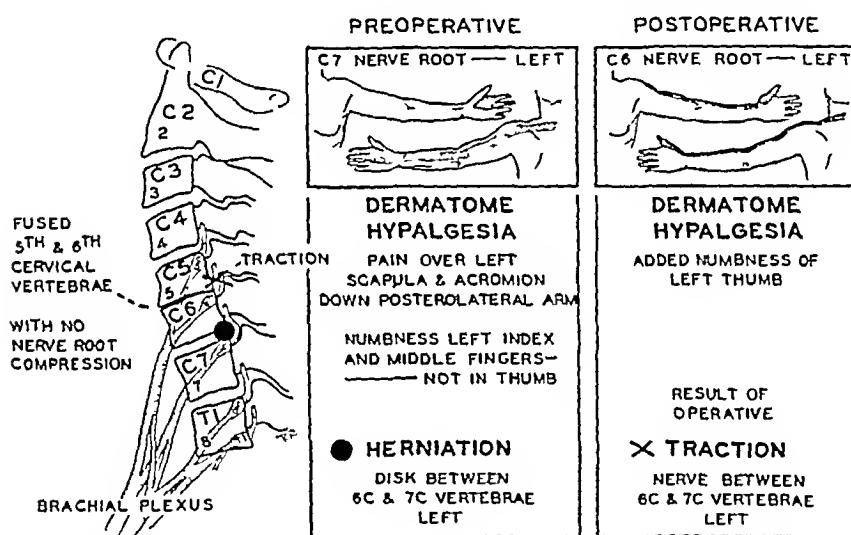


Fig. 20 (case 13)—Cervical portion of the spine with obliterated disk between the fifth and the sixth vertebra. Hypalgesia of the seventh cervical dermatome indicated herniation of the normal-appearing disk between the sixth and the seventh vertebra, verified surgically. Operative traction on the sixth cervical nerve root produced added dermatome hypalgesia of this root.

of the normal-appearing fourth lumbar disk, the diagnosis being verified and the condition relieved by operation.

CASE 12 (fig. 19)—A rather complicated sequence of multiple herniations of intervertebral disks and diagnostic dermatome hypalgesia developed over a period of four years. Pain radiating down the anterior surface of the right thigh and hypalgesia in the distribution of the fourth lumbar nerve root in 1941, with spinogram and operation, verified the herniation of the third lumbar disk on the right side. In the following year, 1942, similar pain and hypalgesia on the left side, with appreciable narrowing of the third lumbar disk, indicated left-sided herniation of this disk, verified surgically. Three years later pain again developed in the right leg, but this time it was located more laterally than anteriorly and the dermatome hypalgesia indicated compression of the fifth lumbar nerve root. The old third

lumbar disk was further narrowed. Without regard for the new neurologic signs, the third lumbar disk was reexplored, without encountering further herniation. Exploration of the fourth lumbar disk disclosed a discrete herniation of the nucleus, compressing the right fifth lumbar nerve root, as indicated by the dermatome hypalgesia.

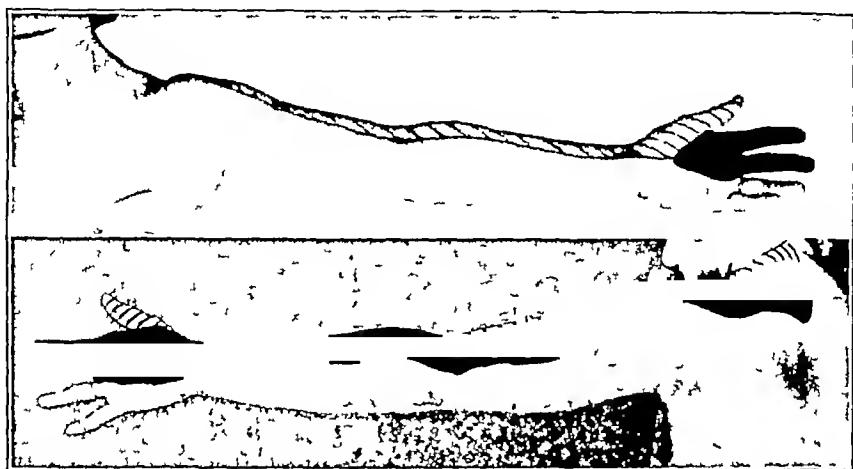


Fig. 21 (case 13)—Photograph of area of faintly reduced pain sensation, or hypalgesia, outlined for the seventh and sixth cervical nerve roots

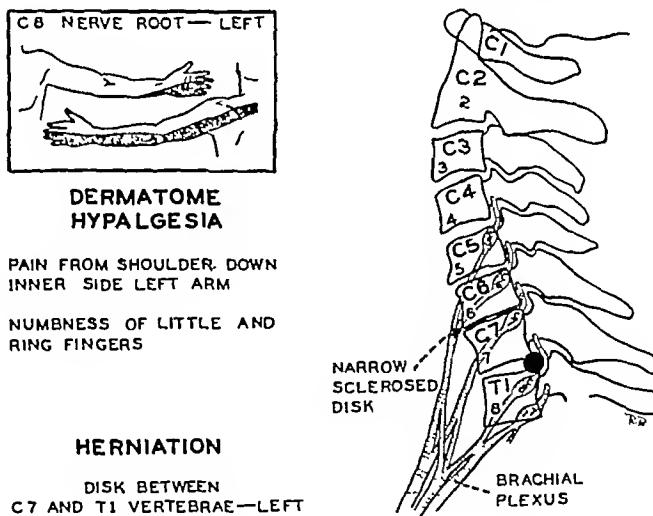


Fig. 22 (case 14)—Cervical portion of the spine with narrow, sclerosed disk between the sixth and the seventh vertebra. Hypalgesia of the left eighth cervical dermatome indicated herniation of the disk between the seventh cervical and the first thoracic vertebra, verified surgically

In the lower cervical region, narrowing of intervertebral disks and surrounding hyperostosis of vertebral borders are observed commonly in roentgenograms, without nerve root symptoms, even when

oblique views may show the hyperostosis encroaching on the intervertebral canal. However, compression syndromes referable to a single nerve root do occur in this region and can be as well defined by dermatome hypalgesia as in the lumbar region.¹⁴ Time cannot be taken to discuss this syndrome but it again should be emphasized that the presence of pain and dermatone hypalgesia over the scapula, arm and hand referable to a single nerve root necessitates interpretation of a lesion of that nerve root, regardless of roentgenographic evidence of lesions elsewhere in the cervical portion of the spine. Two illustrations of pathologic involvement of the cervical portion of the spine, with findings referable to the nerve roots, are presented.

CASE 13 (figs 20 and 21)—Severe pain and dermatome hypalgesia occurred in the distribution of the left seventh cervical nerve root. Roentgenograms of the

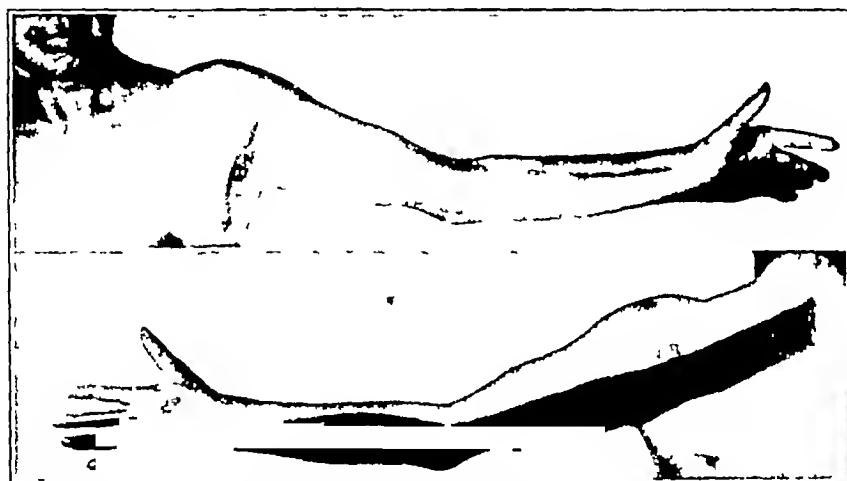


Fig. 23 (case 14)—Photograph of area of faintly reduced pain sensation, or hypalgesia, outlined for the left eighth cervical nerve root, showing atrophy of the intrinsic muscles of hand.

cervical region of the spine showed complete obliteration of the disk between the fifth and the sixth cervical vertebra, a lesion which would not involve the seventh cervical nerve root. Operation demonstrated the herniation of the nucleus at the proper anatomic site, between the sixth and the seventh vertebra. The sixth cervical nerve root was explored, and traction on it produced an increased sensation of numbness in the thumb and hypalgesia characteristic of the distribution of this root, with transient extensive motor impairment from loss of function of two nerve roots.

CASE 14 (figs 22 and 23)—The patient presented pain and hypalgesia typical of compression of the left eighth cervical nerve root, with motor loss in the intrinsic muscles of the hand. Roentgenograms showed a narrow, sclerosed disk between the sixth and the seventh cervical vertebra, a lesion which would not involve the eighth cervical nerve root. Operation demonstrated a herniation of the nucleus at the proper anatomic site, between the seventh cervical and the first thoracic vertebra.

with no herniation over the sclerosed disk above. The pain and motor loss were relieved by release of the nerve root, some hypalgesia persisting.

SUMMARY

The finding of diagnostic areas of sensory reduction, or hypalgesia, with loss of a single nerve root has made possible the accurate identification and location of nerve roots in their relation to vertebral sequence and abnormality.

Progress in this field of neurologic diagnosis has been retarded by acceptance of the dictum that loss of a single nerve root produces no loss of sensation, by failure to test accurately for this loss of sensation and by lack of recognition that posterolateral herniation of the nucleus pulposus of an intervertebral disk commonly compresses only one nerve root.

New dermatome charts for the lower and the upper extremities have been combined with the standard dermatomes of the trunk to furnish a new dermatome chart of the human body, which should be useful in neurologic diagnosis and anatomic teaching.

An accurate history of distribution of pain in cases of compression of a single nerve root by posterolateral herniation of an intervertebral disk often suffices to indicate the nerve root involved if this new dermatome chart is used for interpretation.

Anatomic teaching that there is an outward migration of dermatomic nerve loops and sensory areas in development of the limb bud, and that there are great variation and forward transmutation and suppression of vertebral and nerve segments in the human spine as compared with that of the lower primates is not supported by the evidence presented.

This study indicates that there is no change of position of the nerve roots with addition or reduction of lumbar vertebrae in man if the vertebrae are counted in total numerical sequence, and not by an arbitrary lumbar series defined by a quite variable first sacral segment and last rib.

The nerve roots and plexuses to an extremity should be considered as a unit which includes all nerve roots to that extremity, such as the first lumbar to the fourth sacral nerve root to the lower extremity in man. Separation or fusion into plexuses is a secondary arrangement which does not alter the ultimate root distribution to the skin.

The sacrum of lower primates is composed of three segments, the twenty-seventh, twenty-eighth and twenty-ninth vertebrae of the total series. Addition or fusion of vertebrae above these segments to meet postural needs does not alter the segmental distribution of nerve roots in the total series.

The terminology of the human vertebrae, intervertebral disks and nerve roots is confusing, particularly in describing compression of a nerve root by herniation of an intervertebral disk. It would be simpler and more accurate to identify the vertebrae by means of a total numerical series, with the corresponding disk and nerve root immediately below.

Abnormalities of the lumbar or the cervical portion of the spine seen in roentgenograms should be interpreted independently of definitely lateralized pain and hypalgesia referable to nerve roots, as the latter is more accurate in localizing compression of the nerve root by postero-lateral herniation of the nucleus pulposus of an intervertebral disk.

The important fundamental significance of this new delineation and interpretation of the cutaneous distribution of the segmental nerve roots in the extremities of man has not yet been recognized fully by neurologists and anatomists, but the number of cases on which it is based and its demonstrated dependability in neurologic diagnosis indicate that it will be generally accepted in time.

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DISCUSSION

DR. ROBERT D. SCHROCK, Omaha (read by Dr. Kellogg Speed, Chicago) This excellent presentation by Dr. Keegan is limited to the diagnostic aspects of a condition producing pain in the lower part of the back and the lower extremity. For years a problem has been presented in disabilities concerned with the lower part of the back, evidenced clinically by a list of the trunk or scoliosis and reference of pain to the sciatic nerve. Textbooks use the term sciatic scoliosis for this syndrome. In the past ten years, a certain group of patients with this disability has been segregated by more detailed study, and it has been demonstrated that the so-called sciatica can be further divided according to the component parts of the nerve or the individual nerve roots. In other words, detailed study has personalized the components of the sciatic nerve, so that in this group of patients it can be stated that the pain is due to irritation of one of the nerve roots of the sciatic nerve. Dr. Keegan has demonstrated a simple, and in my experience a dependable, method for localization of lesions of the individual nerve root through changes in its sensory distribution.

This localization does not correspond with the older conception of the absence or indefinite localization of sensory signs with lesions of a single nerve root. It is difficult to cast aside ideas received in the formative years and regarded as true because they represented the best information then available. Dr. Keegan has demonstrated definite areas of reduction of epieritic sensation from loss of function of an individual nerve root in the extremities, and from this he presents a new dermatome chart.

It has been my privilege to watch closely the development of these dermatome patterns and to check personally with Dr. Keegan my findings against his own, and it is pleasing to note the high frequency of agreement as to localization. Our lack of agreement is coming closer to explanation as Dr. Keegan clarifies the problem by his consideration of the total numerical series of vertebrae rather than the age-old classification of cervical, dorsal, lumbar, sacral and coccygeal vertebrae. He has given through illustrative cases an answer to a question fre-

quently regarded as of no importance. The question is whether in certain cases of congenital malformations at the lumbosacral level an individual vertebra is lumbar or sacral. It has been the common fault to employ the loose designation of lumbarized first sacral or a sacralized fifth lumbar vertebra for such an abnormal vertebra, depending on the major characteristics of the individual vertebra. Dr Keegan shows the importance of exact identification for determination of the position of the involved nerve root.

This paper, based on analysis of over 1,000 cases of disabilities of the lower part of the back with unilateral signs of nerve root involvement, in only 57 per cent of which there have been operative attacks, indicates Dr Keegan's conservatism. The discussion could reasonably have been made to cover the entire problem of pain in the lower part of the back, but the presentation was based entirely on the diagnosis of disability of the lower part of the back with lateralized pain.

Dr Keegan, in our almost daily discussions, sometimes developing into stimulating arguments, does not claim, as have some neurosurgeons, that all disabilities of the lower part of the back are due to herniation of the nucleus pulposus of an intervertebral disk. He presents a dependable technic for evaluation and accurate localization of compression of nerve roots in certain types of disability of the lower part of the back with pain radiating into one lower extremity. In my experience, the technic is simple and accurate.

extradural space, or there was a definite bulging of the disk into the spinal canal, and when the annulus fibrosus was opened the nuclear material mushroomed spontaneously into the epidural space. Of the 80 pathologic disks, 51 were definitely protruding but had not completely ruptured through the annulus fibrosus, and 29 had ruptured completely through the annulus fibrosus, the nuclear material lying free in the epidural space. In 10 of the total series of 90 cases, neither of these two criteria was fulfilled, for this reason, the findings at operation in these cases were considered negative. These criteria for pathologic disk are, perhaps, more rigid than those set up by most surgeons, when, however, either condition is present, every one familiar with such lesions would agree that the disk is pathologic. On the other hand, the terms "concealed disk" and "protruded disk" are used by some surgeons to designate the condition of disks which they consider abnormal. Whether a disk so designated is abnormal is questionable, certainly, there is much room for personal interpretation and speculation on the part of the surgeon who is faced with the choice of an exploration without results or the consolation of a diagnosis of a pathologic disk of this indefinite type. Because of variations in structure of the disk, it is difficult, if not impossible, to determine at operation whether a disk is abnormal merely by its consistency. It is true that the herniated disk has a typical bulging appearance and a soft, boggy consistency, but these signs are open to so much individual interpretation that their acceptance alone as evidence of a pathologic disk may be quite inexact and, therefore, evaluation of results in cases of this type would be correspondingly misleading. Analysis of the results obtained in these 80 cases of definite lesions of the disk would indicate that operation is followed by satisfactory relief when a lesion of the disk is removed and that spinal fusion does not improve the result. It has been unnecessary to perform a second operation to cut sensory roots or to free adhesions or to carry out any other procedure for relief of continued pain in any of these cases, except 1 in which spinal fusion was later performed.

In all 80 cases the abnormal disk was observed in the last two lumbar or in the lumbosacral interspace. In 6 cases the lesion was in the interspace between the third and the fourth lumbar vertebra, in 28 cases (35 per cent), in the interspace between the fourth and the fifth lumbar vertebra, and in 46 cases (58 per cent) in the lumbosacral interspace. This distribution follows closely the experience of other investigators.²

1 This period was chosen because the results for all patients operated on prior to Aug 1, 1942 have previously been reported by Peyton and Levin.⁶

2 (a) Smith, A. D., Deery, E. M., and Hagman, G. L. Herniation of the Nucleus Pulposus. A Study of One Hundred Cases Treated by Operation, *J. Bone & Joint Surg.* **26**: 821, 1944. (b) Verbruggen, A. H. Herniated Nucleus Pulposus

The disease was found to be much more common in men (60 cases) than in women (20 cases). The age incidence of the patients varied from 20 to 60 years, with the maximum number of patients in the 36 to 45 age group. These findings are similar to those reported by Bradford and Spurling.^{2c} No significant correlation could be found between the age of the patients and the interspace involved by the pathologic disk.

The symptoms and signs presented by the patients were analyzed in an attempt to demonstrate any significant difference in relation to the interspace involved. Abnormal reflexes were found to vary to some extent, depending on the interspace, but otherwise no significant correlation could be made between symptoms or signs and the interspace involved.

Table 1 shows the incidence of reflex changes found in these cases. As would be expected, the achilles reflex, the arc of which is chiefly in the first sacral root, was diminished or absent in a significantly greater

TABLE 1.—Changes in Reflexes in Relation to Interspace Involved

	Location of Disk			Total	No Disk Seen at Operation
	L 3	L 4	L 5		
Quadriceps reflex					
Normal	3	23	34	60	8
Diminished or absent	3	3	11	17	0
No record	0	2	1	3	2
Achilles reflex					
Normal	1	12	6	19	5
Diminished or absent	5	15	38	58	4
No record	0	1	2	3	1

percentage of cases of herniated disk at the fifth than at the fourth lumbar interspace. However, in 5 of the 6 cases in which the lesion was at the third lumbar interspace the achilles reflex was also diminished or absent, but in this group were 2 cases in which the lesions were so large that they produced paraplegia. This tendency of herniations of the disk at the third lumbar interspace to be massive may explain the high incidence of abnormal achilles reflexes associated with this group. It is surprising to find that the quadriceps reflex was recorded as decreased in 11 cases with lesions at the fifth lumbar interspace, since the arc of this reflex is generally accepted as in the second, third and fourth lumbar segments. These reflexes were tested in all cases by experienced examiners so we feel that the findings are reliable. It is possible that the reflex in these cases was only apparently diminished, owing to a protective muscle spasm as a result of pain.

Two patients were admitted to the hospital with paraplegia. It is remarkable that both these patients had a lesion of the disk at the third lumbar interspace, where only 6 (7 per cent) of the lesions occurred. This experience with lesions at the third interspace producing paralysis, together with other reports in the literature, is indicative of a tendency of massive herniations to occur in this interspace. In 2 cases of herniated disk with paraplegia reported by Voris³ the herniations were at the third lumbar interspace. Verbruggen⁴ reported 8 cases of massive extrusion of an intervertebral disk verified at operation. In 2 of these cases the lesion was at the third lumbar interspace.

That the return of function after operation in cases with severe compression of the cauda equina is unsatisfactory was shown by the report of Verbruggen.⁴ Of the 8 cases in which he operated, the results were excellent in 1, good in 1, and fair in the other 6. In all the last 6 cases there was residual weakness, anesthesia or loss of sphincter control of varying severity. Voris,³ on the other hand, reported that the symptoms were relieved by removal of the lesion of the disk. Our experience with 2 cases has been similar to that of Verbruggen. In both cases residual weakness and sensory changes of severe degree were present, and in 1 case severe impairment of the urinary sphincter persisted.

The pathologic group was compared with the nonpathologic group for significant difference in symptoms and signs. The incidence of typical symptoms and physical findings was somewhat less constant in those cases of the nonpathologic group, but almost every so-called typical symptom and finding of a lesion of the disk was present, in one or another of the cases in which no lesion was seen at operation, and sometimes several were present in a single case. When these differences in symptoms and signs are subjected to statistical analysis for significant differences, it is found that only the incidence of a history of exacerbations and remissions, incapacity for work and tenderness of the sciatic nerve were significantly different, being higher in the pathologic group.⁵

Of the 80 cases in which pathologic disks were proved to have been present, an unequivocal history of trauma was given in 63 (79 per cent). This is a higher incidence of trauma than has been reported by other authors⁶ and is also higher than that in the previous series of cases of

3 Voris, H C. Sudden Extrusion of an Intervertebral Disc, *Dis Nerv System* **6** 80, 1945.

4 Verbruggen, A H. Massive Extrusions of the Lumbar Intervertebral Discs, *Surg, Gynec. & Obst* **81** 269, 1945.

5 The data were tested by Fisher's "exact" test.

6 Spurling, R G, and Thompson, T C. Notes on the Diagnosis of Herniated Nucleus Pulposus in the Lower Lumbar Region, *Surgery* **15** 387, 1944. Verbruggen^{2b} Bradford and Spurling^{2c}

herniated disk reported from this clinic.⁷ Of the 10 cases in which no lesion was observed at operation, a definite history of trauma precipitating the illness was present in 6 (60 per cent).

The onset of symptoms was acute in the majority of the cases. This was true of both the cases with and the cases without pathologic disk. The duration of symptoms varied from one month (in a case of paraplegia) to twenty years. There was no significant difference between the pathologic and the nonpathologic groups as to duration of the symptoms.

All the patients in both groups complained of pain in the back. Sciatic pain was present in 89 cases. Only 1 man, in whom a pathologic disk was found, had not had pain in the distribution of the sciatic nerve. Pain was aggravated by coughing, sneezing or straining in 65 (81 per cent) of the cases in which a pathologic disk existed and in 6 (60 per cent) of the cases in which exploration revealed no lesion of the disk. In 69 (86 per cent) of the cases of pathologic disk there were histories of exacerbations and remissions of symptoms, while in 4 (40 per cent) of the cases of nonpathologic disk a similar history was obtained.

In 70 cases (87 per cent) of the pathologic group there was a history of complete incapacity for work for at least one week. In most cases, of course, capacity for work was impaired for a much longer period. Incapacity for work was also found in 5 (50 per cent) of the nonpathologic cases.

Scoliosis was observed in approximately one third of the cases in both the pathologic and the nonpathologic group. There may be a list to the side of the lesion or to the opposite side. A list to the side opposite the lesion was about twice as frequent as a list to the side of the lesion. Spasm of the paravertebral muscles was noted in 36 cases (45 per cent) of the pathologic group and in 4 cases (40 per cent) of the nonpathologic group. In 45 cases (56 per cent) of the abnormal group, tenderness was maximal over the involved interspace, and in another 20 cases (25 per cent) tenderness was present but was maximal over an uninvolved intergroup. In 45 cases (56 per cent) of the abnormal group, tenderness was present over an interspace. Tenderness over the sciatic nerve was noted in 35 cases (44 per cent) of the pathologic group and in 4 cases (40 per cent) of the nonpathologic group. Pain resulting from maneuvers which stretch the sciatic nerve was present in 75 cases (94 per cent) of the pathologic group and in 5 cases (50 per cent) of the nonpathologic group. In 14 cases (17 per cent) of the pathologic group stretching of the sciatic nerve on the uninvolved side produced pain in the leg on the involved side. This observation was not made in any of the cases in which later exploration revealed no lesion. Weakness and atrophy of the muscles of the leg were seen in only a small number of cases, but no

⁷ Peyton, W. T. and Levin, I. D. Posterior Herniation of the Intervertebral Disc. An Analysis of Sixty-Five Cases, Minnesota Med. 27:263, 1944.

definite conclusions can be drawn regarding these findings because of the incompleteness of the records concerning this sign. Significant sensory changes were found in 38 cases (47 per cent) of pathologic disk and in 3 cases (30 per cent) of normal disk. This is a lower incidence of sensory disturbances than has commonly been reported to occur in this disease.²

Three of the 90 operations were reoperations for lesion of a disk in cases in which a pathologic disk had been removed previously. In all 3 operations a second pathologic disk was encountered. In 1 case the recurrence was at the same interspace, and in the other 2 cases a different interspace was involved. This incidence of involvement of a second interspace is so much greater than the incidence of lesions of the disk in the general population that it suggests that some degenerative change may be present in the intervertebral disks of certain people as the underlying cause of herniation of the nucleus pulposus.

A spinal fusion was performed in 1 case one year after the removal of a pathologic disk. This was done in an attempt to relieve the pain in the back, which had not completely disappeared on removal of the disk. The fusion did not change the severity of this pain. During the period under consideration, no other reoperations were performed—for section of sensory roots, spinal fusion or any other procedure for the relief of continued pain.

Routine anteroposterior and lateral roentgenograms of the lumbosacral portion of the spine were taken before operation and revealed that in 7 of the 90 cases there existed varying degrees of lumbarization of the first sacral vertebra, in 1, spondylolisthesis, and in 1, spina bifida occulta. This is a smaller incidence of these abnormalities than was recorded by Breck, Hillsman and Basom⁸ in their review of 450 routine lumbosacral roentgenographic examinations on work applicants. This fact is of significance, since Deery⁹ stated that preexisting instability of the back predisposes the patient to herniation of an intervertebral disk. This analysis of 90 cases would indicate that bony abnormalities evident on roentgenographic examination, which are thought to produce instability, are not predisposing causes of herniation of an intervertebral disk.

Narrowing of the interspace involved by the pathologic disk was observed in roentgenograms in 16 cases, but such narrowing was also found in an interspace other than the one involved in 8 cases. Narrowing of the interspace was also observed in 3 cases in which no lesion of the disk was seen at operation.

⁸ Breck, L. W., Hillsman, J. W., and Basom, U. C. Lumbosacral Roentgenograms of Four Hundred and Fifty Consecutive Applicants for Heavy Work, *Ann. Surg.* **120**: 88, 1944.

⁹ Deery, E. M. Herniation of the Nucleus Pulposus as a Complication of Preexisting Low Back Instability, *Surg., Gynec. & Obst.* **77**: 79, 1943.

There has been expressed in the literature a considerable difference of opinion concerning the importance of myelography as a diagnostic aid in this disease, and there is also variable opinion as to the type of contrast medium to be used if myelographic examination is made Love¹⁰ recommended the use of air myelograms in all cases Verbruggen¹¹ expressed the belief that the use of myelography is unwarranted Key¹¹ stated that the myelographic procedure is no more accurate than a good physical examination In this clinic air myelography was discarded in 1941 because it was felt that the interpretation of air myelograms was unreliable Since that time, myelographic studies with iodized poppyseed oil 40 per cent or "pantopaque" (a mixture of ethyl esters of isomeric iodophenyl undecylic acids) has been used in selected cases Many patients present such classic symptoms and signs that myelographic study is considered unnecessary, since an operation would be performed even if the myelograms showed no lesion In other cases in which the findings are less definite, myelographic examination is carried out because the decision as to whether or not an operation should be performed may depend on the additional evidence obtained from the findings Myelograms were made in 46 of the 90 cases A correct roentgenologic diagnosis was made in 41 cases In 3 cases a positive diagnosis of a lesion of the disk was made on roentgenologic examination but subsequent operation showed no such lesion In 1 of these cases, however, there was to account for the defect a definite bony projection, which probably was an old ruptured and calcified disk Since this, however, did not satisfy our criteria of a pathologic disk, the myelographic diagnosis is here recorded to be in error, but the reverse is probably true In 1 case the myelographic evidence was negative, but subsequent operation (within two weeks) proved that a large pathologic disk was present In the fifth, and final of the cases in which the roentgenographic diagnosis was incorrect, the iodized poppy seed oil was injected into the subdural space an occasional fault in technic which makes interpretation of the roentgenograms impossible There were, therefore, two false positive and one false negative myelogram¹²

In 1 of the 90 cases the ligamentum flavum was found to be definitely abnormal There was degeneration of the ligament Its central portion was replaced by caseous material, so that when it was first exposed and

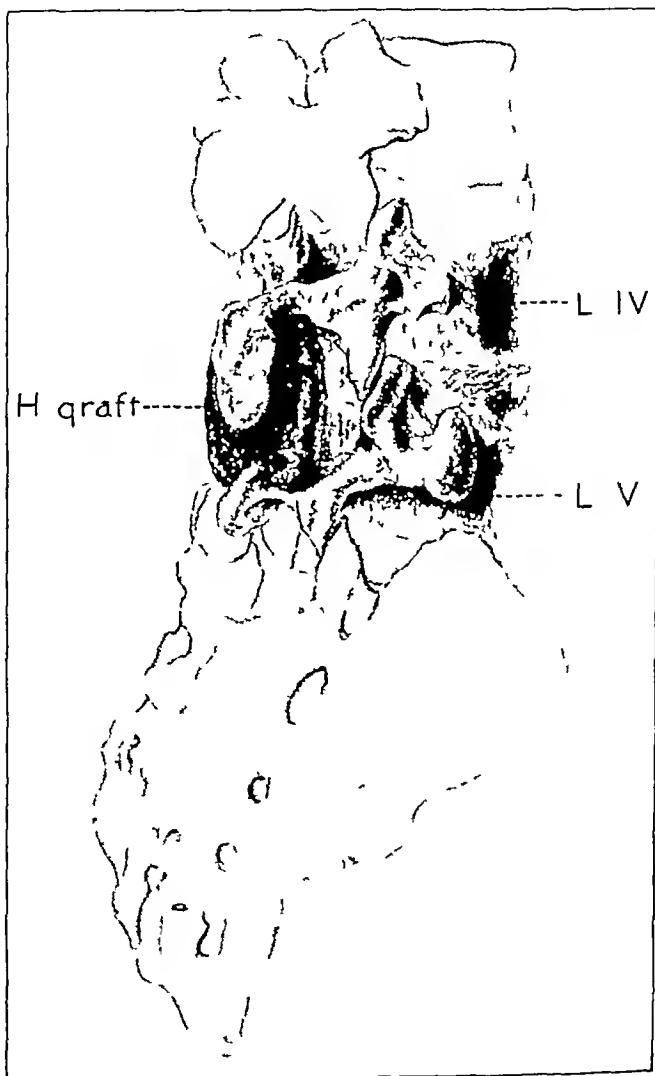
10 Love, J. G. The Differential Diagnosis of Intraspinal Tumors and Protruded Intervertebral Discs and Their Surgical Treatment. *J. Neurosurg.* **1**: 275, 1944

11 Key, J. A. The Conservative and Operative Treatment of Lesions of the Intervertebral Discs in the Low Back. *Surgery* **17**: 291, 1945

12 All myelographic studies were performed and interpreted by Dr H. O. Peterson of the department of roentgenology.

incised it appeared to contain a small dermoid cyst. Associated with this abnormal ligament was a pathologic lesion of the disk.

The surgical procedure employed at this clinic is similar to that in general use except that in all cases in which operation was done after March 1944 a spinal fusion was performed, using a Gibson¹³ type of dovetailed bone graft (figure). At first these grafts were obtained



Spinal fusion with the Gibson type of bone graft

from the tibia, but later they were taken from the crest of the ilium. With the spine flexed to separate the spinous processes, the graft is wedged tightly between the spines at the site of the involved disk. On

13 Gibson, A. A Modified Technique for Spinal Fusion, *Surg., Gynec. & Obst.* 53: 365, 1931.

return from the flexed position, the graft becomes solidly wedged between the spinous processes. Bone grafts of this type were used in 45 cases in which a lesion was observed on exploration and 2 in which no lesion was encountered.

Postoperative complications were not frequent. Death due to pulmonary embolism occurred in 1 case and wound infections, in 2 cases. In 1 of the cases, with a massive compression of the cauda equina, urinary incontinence was present before operation, and this has remained as one of the most distressing symptoms. In 2 other cases there was temporary loss of control of the urinary sphincter, but in both cases this cleared completely before the patients' discharge from the hospital, three weeks after operation.

Grant,¹⁴ in a survey of the postoperative results in 150 cases, found the patient at work with no pain in 52 per cent, working but with some disability in 37 per cent and not working in 11 per cent. Shinners and Hamby,¹⁵ in a follow-up study, found that 54 per cent of their patients had some residual pain in the leg and 57 per cent had pain when working. Verbruggen^{2b} classified his results in 75 cases as excellent (15 per cent), good (68 per cent), fair (11 per cent) and poor (6 per cent).

We have been able to follow 79 of the 90 patients in the outpatient clinic for a period of at least six months after operation, the average period for which these patients were followed being slightly over eighteen months. Only patients who were seen and examined are included in this analysis, for we find that many who claim on casual conversation that they have no symptoms admit on careful cross examination that some symptoms are present. Table 2 is a recording of the results for the patients thus followed. Not all findings recorded in these follow-up examinations are included in table 2. Each patient was also examined for pain on stretching the sciatic nerve, paravertebral muscle spasm, paravertebral tenderness, atrophy of the involved leg and reflex changes, but the results are not tabulated because they did not seem to add anything significant to evaluation of the functional result. The results in the cases in which bone grafts were made after removal of a pathologic disk (45 cases) and those in which no graft was made (35 cases) were recorded separately in table 2 so that the results might be compared.

Statistical analysis of the differences in table 2 reveals that there is no significant difference in the results for cases with bone graft and for cases without bone graft but unsatisfactory results are significantly more

14 Grant, F. C. Operative Results in Intervertebral Discs. *J. Neurosurg.* 1: 332, 1944.

15 Shinners, B. M., and Hamby, W. B. The Results of Surgical Removal of Protruded Lumbar Intervertebral Discs. *J. Neurosurg.* 1: 117, 1944.

frequent in the group without pathologic disk than in the group with pathologic disk.

The results following operation for lesions of the disk are divided into two large groups, satisfactory and unsatisfactory. No case was included in the group of satisfactory results if the patient had any disability whatever in his usual occupation, and many of these patients have occupations which require strenuous physical exercise.

TABLE 2.—*Results Following Operation*

	No Bone Graft Used		Graft Used		Total		No Herniation of Disk at Operation	
	No. of Cases	Per Cent	No. of Cases	Per Cent	No. of Cases	Per Cent	No. of Cases	Per Cent
Total number of cases	31		41		72		1	
Results								
Satisfactory								
No symptoms	5	16	9	22	14	19	1	1
Minor symptoms	20	65	28	68	48	67	1	1
Unsatisfactory *								
Improved	4	18	2	5	6	8		
Not relieved or severely handicapped	2	6	2	5	4	6	1	1
Pain in back								
Present	22	71	27	66	49	68	6	5
Absent	9	29	14	34	23	32	1	1
Pain in legs								
Present	16	52	29	71	45	62.5	5	2
Absent	15	48	12	29	27	37.5		
Impairment of work capacity								
None	29	94	37	90	66	92		
Slight	0		2	5	2	3		
Moderate	1	3	0		1	1		
Severe	1	3	2	5	3	4	1	1
Paresthesias								
Present	15		14		29			
Absent	16		27		43			
Weakness of leg								
Present	5		4		9		1	
Absent	26		37		63		6	
Sensation								
Normal	23		27		50		5	
Impaired	8		14		22		2	

* Since this report was written and these computations were made, an unsatisfactory result has been found in 1 of the previously untraced cases in which fusion was not done.

The group with satisfactory results was further divided into subgroups, one including patients with no symptoms and the other patients with minor symptoms. These minor symptoms were mild discomfort of the back, mild pain in the leg, stiffness of the back or legs or annoying paresthesias.

The group with unsatisfactory results included patients who were improved but whose symptoms were sufficiently severe so that they were to some extent incapacitated for their usual occupations. Ten patients were included in this classification, 6 of whom are recorded as showing improvement and 4 as not relieved or as severely handicapped.

Mere tabulation of the results for these 10 patients as unsatisfactory, without further comment, would give an unpropitious impression of the results of operation for herniated disk as observed in this group of followed patients. Since it seemed desirable to set up certain criteria for each group in the classification of results and to adhere rigidly to these criteria, every patient who, after returning to work, was incapacitated for carrying on his usual occupation for as long as one week was classified as unsatisfactory, but the results for most of them were much better than this designation "unsatisfactory" would imply.

Therefore, a brief account of each of the 6 cases classified as showing an unsatisfactory result but improvement follows.

CASE 1—A lesion of the disk was removed in June 1940 from the left side of the space between the second and third lumbar vertebrae of a farmer aged 41. He has been followed in the outpatient clinic at regular intervals since that time. He complained of pain in the left lower extremity when active but could tolerate up to four hours of light work, and up to July 1944 he was quite comfortable if inactive. At this time he cranked an automobile and had sudden severe pain in the right buttock, which forced him to remain in bed for one week. Intermittent episodes of pain on the right side then kept him completely incapacitated until February 1945, when a second lesion of the disk was removed from the space between the fourth and fifth lumbar vertebrae on the right side. Since this second operation he has again been rehabilitated to about the same work capacity he had before the appearance of pain on the right side, in 1944. His complaints since the second operation, however, have been in the left lower extremity.

CASE 2—A physician aged 33 had a lesion of the disk removed from the right side of the fifth lumbar-first sacral intervertebral space and spinal fusion performed on Oct. 4, 1944. He was completely free of pain for four weeks and then experienced pain in the lower part of the back and down the distribution of the left sciatic nerve. Two weeks after onset of the pain in the left lower extremity he was put to bed with 15 pounds (6.8 Kg) of traction, with prompt relief. The traction weights were gradually removed, and he was again out of bed and free of pain eight days after the traction was applied.

Since that time he has had no pain or distress in the back, and were it not for the fact that he had the aforementioned attack, which appears to have been due to irritation of the nerve roots on the side opposite the lesion of the disk, the result would qualify as excellent.

CASE 3—A lesion of the disk was removed on Jan. 8, 1945 from the right side of the fifth lumbar-first sacral intervertebral space of a chauffeur aged 55. He was relieved of pain until April 2, 1945, when he again experienced pain radiating down the right leg. After approximately three weeks in bed his pains had completely subsided, and he returned to work and remained free from symptoms until Dec. 20, 1945, when he again had pain for two days but since then or for the past year, he has had no pain and has worked continuously.

In this case, the result would be very satisfactory were it not for two short periods of recurrent pain since his operation nearly two years ago.

CASE 4—A farmer aged 44 had an exploration of the left side of the fifth lumbar-first sacral intervertebral space on March 1, 1943. A very small fragment of loose disk material seemed to be present but there was doubt even at the conclusion of the operation whether a lesion of the disk was really present.

Two months after operation he had less sciatic pain than before operation but was not entirely relieved. One year after operation he was doing light work, such as gardening and driving a tractor, but he still had pain in the lower part of the back and in the distribution of the right sciatic nerve when he did heavy farmwork.

It is quite possible that this case belongs in the group of negative results of exploration for lesion of the disk.

CASE 5—On July 17, 1943, a lesion of the disk was removed from the right side of the space between the fourth and fifth lumbar vertebrae of a packing plant laborer. He did not go back to work until three months after operation. In the interval, and for two weeks after he returned to work, he was entirely free of pain, then he began to have pain in the distribution of the right sciatic nerve. This increased gradually, so that he was obliged to stop work after five weeks, when the pain gradually subsided.

Seven months after operation he reported that he was entirely free of pain when inactive or unless he became chilled, but he resented the fact that he was assigned work in the cooler room of the packing plant.

Because of continued disability, a fusion of the fourth and fifth lumbar vertebrae was performed March 22, 1944, or approximately eight months after the lesion of the disk was removed. This did not result in any essential change in his condition. He continued to complain when assigned to work in the cold room of the packing plant, but when given work in a warm atmosphere worked without complaint.

This is the only compensation case in which an unsatisfactory result followed removal of a lesion of the disk, but in this man there seemed to be a relation between his pain and dislike for the work to which he was assigned.

CASE 6—A completely herniated lesion of the disk lying free in the epidural space was removed on Jan. 23, 1943 from the left side of the fifth lumbar-first sacral intervertebral space in a housewife aged 48. Two months later she reported that her condition was improved but not cured. Seven months after operation she reported that she had pain in the opposite, or right, lower extremity, but it was relieved by rest in bed. One year later, or eighteen months after operation, she was entirely free of pain, but at the time of writing, almost four years after operation, she again has pain in the lower part of the back and in the left lower extremity but does her own housework. She has also complained since operation of headache, a sensation of pressure on the top of her head, pain in the posterior cervical region, insomnia and numbness of her hands. Examinations since operation have never revealed any signs of irritation of the nerve roots. It is quite probable that this patient's continued complaints are for the most part, if not entirely, functional.

There were, therefore, in the group of 6 cases, 2 in which relief was obtained except for very short periods of incapacity for work, 1 which probably belongs with the group of negative explorations, 1 in which the continued symptoms seem to be functional in nature and 2 with partial incapacity for work and continued pain without known cause.

There were 4 cases in which very severe handicaps followed operation. In 2 of these 4 cases massive protrusions of the disk produced loss of function in segments below the level of the lesion, and the continued disability was due to incomplete recovery from this paralysis. In 1 of the 4 cases there were a postoperative wound infection and signs of severe involvement of the nerve rootlets from the first lumbar caudal-ward. Spinal puncture nine months after operation revealed that the

protein level of the spinal fluid was 110 mg per hundred cubic centimeters and the fluid was slightly xanthochromic. It is assumed in this case with wound infection that arachnoiditis developed and that this was the cause of involvement of the cauda equina, which extended several segments above the site of the operation. In the fourth, and final, case in this group the patient's condition is considered to be unrelieved. A large lesion of the disk was removed and a spinal fusion performed, with complete relief for eight months, during which time the patient performed the heaviest type of work. Similar symptoms then suddenly developed on the opposite side. A spinogram seemed to demonstrate a lesion in another intervertebral space, but exploration revealed no lesion. Since the second operation, he continues to have pain in his back and in both legs so severe that he is at times incapacitated for work.

There were, therefore, in this group of 4 cases, 2 in which disability was due to incomplete recovery of function in paralyzed segments, 1 with sequelae from a wound infection and arachnoiditis and 1 in which pain, of unknown origin, persisted.

The suggestion has been made that the annoying minor symptoms which persist after the removal of a pathologic disk may be due to long-standing irritation of the nerve root, with permanent structural damage to the root. With this suggestion in mind, comparison was made of the duration of symptoms in the cases with excellent results (no symptoms) and those with good results (minor symptoms). It was found that of the cases with excellent results there were 9 (64 per cent) in which symptoms had been present more than ten years. Of the cases with good results but with residual minor symptoms, symptoms had been present less than six months in 24 (50 per cent) and more than ten years in only 5 (10 per cent). Thus, from this small group of cases, it would seem doubtful whether the duration of symptoms previous to operation affects the result which one may expect from the operation. It was impossible to analyze these two groups in relation to the severity of symptoms because the records did not give sufficiently accurate data on this point. It is realized that severity of symptoms, as well as their duration, should probably be included in an attempt to correlate trauma to the root with the results of operation.

The most common problem in the differential diagnosis of herniated disk, and the one which presents the greatest difficulty, is the differential diagnosis of psychoneurosis and a herniated disk. The symptoms of patients with psychoneurosis relating to the lower part of the back may mimic those of a herniated disk so closely and findings may be so similar that the differentiation is virtually impossible. For this reason, patients suspected of having a lesion of the disk are carefully studied for psychogenic disease before operation.

A critical attitude toward the psychoneuroses in the differential diagnosis of lesions of the disk has been developed in this clinic, for which support is found in the following observations 1 Patients have been observed in this clinic the cause of whose disability was quite probably a psychoneurosis but for whom after prolonged observation, a lesion of the disk could not be ruled out, operation revealed no lesion, and the patient continued to have the same complaints 2 Patients with more obvious psychoneurosis but with some signs of a lesion of a disk have been refused operation and have had exploration elsewhere by a surgeon experienced in this field, without any lesion being encountered 3 Patients have come to this clinic with continuation of their complaints after operation elsewhere by surgeons experienced in operations for lesions of the disk, but on inquiry it has been impossible to get a record of a definite lesion having been observed and removed at the previous operation Many of these persons have been at least temporarily relieved by mere suggestive therapy Limitation of space does not permit the inclusion of illustrative case histories As a rule the results are not good in cases of this type, and the patients are frequently subjected to secondary operations for reexploration, spinal fusion or section of the root

This analysis of the cases in which definite lesions of the disk are removed demonstrates, on the other hand, that results are good and second operations for continued pain are rarely necessary There are, of course, some cases in which both a psychoneurosis and a lesion of the disk are present Some residual symptoms, after the lesion is removed, are probably to be expected in such cases

SUMMARY

Ninety cases in which operation was performed for herniation of a disk are analyzed, with special emphasis on the results of operation The disk was considered pathologic only in cases in which a loose fragment of disk tissue was observed lying free in the spinal canal or in which there were definite bulging and spontaneous protrusion of nuclear material when the annulus fibrosus was opened In all others the disk was considered normal and the results of operation recorded as negative Eighty pathologic and 10 normal disks were exposed at operation

During part of the period covered by the collection of this material, spinal fusions were not performed after removal of lesions of the disk, and during the rest of the period fusion was done in every case after removal of the lesion The relief obtained was essentially the same with simple removal of the lesion as with removal and spinal fusion The results were satisfactory in the group of 80 cases in which a definitely pathologic disk was removed Seventy-two of the patients were followed, and only 3 had continued pain or disability, of unknown origin The results were not good in the 10 cases in which exploration

was considered to have revealed no lesion of the disk. This would indicate that simple removal of the lesion of the disk is a satisfactory operation and that improvement in results is likely to be realized through better selection of cases for operation rather than through the introduction of new operative procedures.

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DISCUSSION

DR J JAY KEEGAN, Omaha. This thorough analysis of 90 cases in which operation has been performed for herniation of a lumbar intervertebral disk, with comparison of results with and without spinal fusion, should aid in the solution of the problem of this syndrome. Every physician has the problem to deal with, for the condition is common, and it is important to seek better definitions of diagnosis and treatment. In such a complicated matter, it is not possible to establish infallible over-all rules, but each case must be analyzed individually and clear thinking and balanced judgment exercised.

There are two elements in this syndrome, as indicated by the familiar description of pain in the lower part of the back and sciatic pain. Pain in the lower part of the back is difficult to interpret in relation to ruptured intervertebral disk or other pathologic condition. In nearly every case in which true herniation of the nucleus pulposus of a disk develops, as defined in this study, initial pain is limited to the midline of the back and cannot be differentiated well from similar pain of other causes. It is only when the loose nucleus has protruded enough to compress a nerve root that pain becomes lateralized, and this should give the first clue that the lesion is a developing true herniation.

This lateralized pain may be represented at first only by an obvious list or protective scoliosis, but the patient will usually state, if questioned carefully, that the greater pain now is slightly to one side of the back or in the sacroiliac region. This early lateralized pain should be recognized as involving the nerve root, chiefly the posterior primary division of the nerve root, and should not be attributed to the ligaments or structures which this nerve division supplies. Later the anterior primary division of the nerve root becomes compressed sufficiently to send radiating pain down the thigh and leg in characteristic distribution for that nerve root.

When complete involvement of the single nerve root develops, sometimes rather suddenly, and persists more than two or three weeks, it usually means that the nucleus pulposus has completely herniated through the annulus and the posterior longitudinal ligament. The patient then will often volunteer the statement "The pain used to be in my back and now is all in my hip and leg." Such a syndrome does not call for spinal fusion, regardless of lesions of the lumbar portion of the spine seen in the roentgenograms for the symptoms are entirely those of compression of a single nerve root diagnosable by the finding of dermatome hypalgesia.

As indicated by the absence of pain in the midback, the remaining annulus is firm and stable. If surgical intervention for herniation of the intervertebral disk could be limited to this type of case, the results would be excellent as Dr Peyton has shown. However there is a large group of cases in which is prevalent a combined syndrome of nerve root pain and pain in the midline of the back due either to incomplete herniation of the nucleus through the posterior longitudinal ligament or to a more diffuse degeneration of the annulus fibrosus which produces rather than herniates.

These two syndromes may be distinguished to some degree, as the pain associated with discrete herniation of the nucleus is more likely to be intermittent, with "catches" in the back, whereas pain associated with diffuse degeneration of the disk does not show remission to this degree. It is difficult to know when fusion should be performed for such a condition. Sometimes longer waiting will permit the development of a true herniation of the nucleus, which can be removed satisfactorily without spinal fusion.

In the second type of case, with symptoms referable to the nerve root, exploration should be made for possible removal of a partly herniated nucleus pulposus, and fusion be done at that time, the operation depending somewhat on the condition of the nucleus and demonstrable abnormal mobility at the involved interspace. The patient who presents only chronically disabling pain in the midline of the lower part of the back and no symptoms referable to nerve roots can safely have fusion without exploration of the disk.

Although spinal fusion is out of the field of neural surgery, a few anatomic observations may be permitted. Since most pain in the back requiring spinal fusion seems to come from degeneration of the intervertebral disk and instability at the site of the disk, it would seem that fusion within the intervertebral space would be more logical than an attempt to stop motion at this site by placing a strut across the posterior neural arch of the spine. The latter procedure may explain some of the poor results from fusion, together with the difficulty in performing fusion at the recessive angle at the lumbosacral junction, where most instability develops.

DR. JAMES S. HIBBARD, Wichita, Kan. I have been extremely interested in the sensory examination which Dr. Keegan has presented so well today, and I realize its importance. Having noted the emphasis placed on diminution of the deep reflexes, my colleagues and I decided to point out the variation which one would find in 100 normal persons. We picked 50 hospital corpsmen and 50 Navy nurses; it was interesting to note that 22 of the subjects had definite inequality of the ankle jerks. One man had unilateral absence of the ankle jerk, which was not explained. In 1 woman the sign was difficult to elicit, but was present. Therefore in the neurologic examination one should not forget the normal variations.

We had a difficult problem overseas in dealing with sailors and Marines who wished to be on the sick list. In many cases the history was typical of a protruded disk and yet an accurate sensory and motor interpretation was impossible. This group included about 20 per cent of the patients with pain in the lower part of the back or with sciatic pain. They were malingerers but could not be designated as such in the Navy.

The psychoneuroses which Dr. Peyton has described were quite evident when I returned to the States. Cases of psychoneuroses were seen in a United States naval neuropsychiatric hospital at which I was associated with thirty-one psychiatrists. We attempted to work on the problem from the psychoneurotic standpoint. Many of the patients showed definite abnormal neurologic signs, but enough improvement was noted under psychiatric management to rule out a protruding disk.

In the evaluation of patients with pain in the lower part of the back we were helped considerably by a "sign," or "test," which was routine in the general physical examination. We called this test the "heel walking test." The patient was instructed to walk across the room flat-footed, on tiptoe and then on his heels. All our patients with lesions of a disk showed exaggerated pain in the back and leg when walking on the heels.

I should like to mention another group of patients. This group bears directly on the question of spinal fusion at the time of removal of the disk and includes

patients presenting additional lesions or congenital anomalies of the spine. From a neurologic standpoint, these patients may also have a protruded disk which needs removal.

(Slide.) I want to show this film because it illustrates one of the pitfalls of study with "pantopaque." There is a typical defect. This patient did not have pain referable to a nerve root. I am positive that the defect in this case was due to an epidural hemorrhage caused by the needle puncture.

(Slide.) The next roentgenogram also illustrates a possible error in studies with "pantopaque." In this case there appears to be an almost complete block at the fourth lumbar segment. Operation revealed no lesion representing the defect. This error has been seen and discussed by roentgenologists, but is not generally recognized.

(Slide) This roentgenogram, taken with the patient standing, demonstrates lesions of bone in addition to a protruding disk. Impingement of the spinous processes on the vertebra below was first shown to me by Dr. A. L. Bence in 1929. This patient had a condition of this type, and he also had a definite lesion of the disk. At operation the disk was removed, the spinous processes were clipped off, and he had complete relief from the pain in his back and from his nuclear pain.

(Slide) This anteroposterior roentgenogram shows the oblique position of the spinous processes as a result of impingement over a period of many years.

DR. WILLIAM T. PEYTON, Minneapolis. I realize, of course, that there are many causes of pain in the back other than psychoneurosis and herniated intervertebral disk, but most of them are ruled out by physical, neurologic and roentgenologic examinations. The most difficult differential diagnosis is that of herniated disk and psychoneurosis, and most poor postoperative results are in psychoneurotic patients who are subjected to operation for lesions of the disk which are not present.

My associates and I make it our rule not to operate on a patient for a lesion of the disk unless he is disabled, and therefore we do not operate on patients who do not have root pain. There was only 1 patient in this group of 90 who had no pain referable to the nerve root.

We use spinograms as a diagnostic aid when the physical signs alone are not quite definite and decision for or against operation rests on the additional evidence to be obtained from the spinogram. A spinogram is not made if the findings are sufficiently definite that operation would be performed even though the spinogram revealed nothing abnormal. Spinograms were made for 46 of this series of 90 patients. We have seen the same deformity in the spinogram which Dr. Hibbard showed here, that is, almost complete blocking of the spinal subarachnoid space to the iodized poppyseed oil or other contrast medium, and we have become cautious in interpretation, since the associated disk is likely to be normal on exploration.

I still think that the so-called protruded disk is not a pathologic disk. I infer from what Dr. Keegan said that he thinks that it is. By a protruded disk I mean one that projects into the spinal canal but, if opened, does not have loose fragments. It has the consistency of a normal disk. There is considerable anatomic variation in the vertebral disk and protrusion is apparently one of the variants. I know that the majority of surgeons who operate on lesions of the disk agree with Dr. Keegan that the protruded disk is a pathologic disk.

BILATERAL OOPHORECTOMY IN EARLY PREGNANCY

Cesarean Section at Term

H K BONN, MD
LOS ANGELES

Reis¹ stated

Progesterin [progesterone] which is the hormone of the corpus luteum of pregnancy is necessary in adequate amounts not only to prepare the endometrium for implantation but also to inhibit uterine contractions in order that the early pregnancy may remain attached to the decidua. In the early weeks of pregnancy these necessary amounts are produced by the corpus luteum of pregnancy. With the completion of placentation which is usually about the twelfth week the placenta takes over the function of the corpus luteum of pregnancy.

This succinct statement by Reis represents the commonly accepted fact that the presence of an ovary (producing the hormone, progesterone, of the corpus luteum) is necessary for the continuance of a pregnancy during the first twelve weeks. Considerable doubt is cast on such a premise by the case reported by Young² and the case to be reported here, which are similar both as to the acute abdominal condition necessitating operation and the probable duration of the gestation at the time bilateral oophorectomy was done.

A brief summary of Young's case follows:

A farmer's wife aged 31 presented symptoms and signs warranting a tentative diagnosis of ruptured ectopic pregnancy. The previous history was not remarkable except that four years before she delivered a 7 month, macerated fetus; a year later she again became pregnant and delivered a living child at full term.

At operation, a twisted ovarian cyst was removed, the other ovary was diseased and was likewise removed. The uterus was small, and since her last menstrual period was only two weeks overdue the diagnosis of pregnancy was questionable. Recovery from the operation was uneventful. Four and one-half months later the diagnosis of pregnancy was made beyond doubt. A living female child was delivered spontaneously about eleven days after the expected date of confinement. When seen one year later, the patient had been amenorrheic since the birth. The uterus was of normal size and shape, and there was no apparent atrophy.

In Young's case both ovaries were removed on March 23, 1940, and the last menstrual period had been on February 6, thus the preg-

Read at the fifty-fourth annual meeting of the Western Surgical Association at Memphis, Tenn., Dec. 7, 1946.

1 Reis, R A Causes and Treatment of Spontaneous Abortion, Illinois M J 80 380 (Nov) 1941

2 Young, W R Bilateral Oophorectomy in Early Pregnancy, Illinois M J 80 132 (Aug) 1941

nancy could not have been present for more than thirty-five days if one adds ten days to February 6, as the most likely date of conception Young added ten days to February 6, but if one adds fifteen days the commonly accepted time of conception, the pregnancy in his case would have been of only thirty days' duration.

The following case is reported:

Mrs. W. E., aged 30, was seen on Jan. 9, 1943. According to her history, ten years previously, at the age of 20, a cesarean section was done by a competent colleague and friend in a midwestern city. The indication for the section as stated to and by the patient, was the presence of a large intrauterine tumor precluding a normal delivery. A living male child was delivered and the patient was informed by her surgeon that a tumor of the uterus had involved practically the entire fundus and that this tumor had not been removed. Recovery from the section was uneventful.

Two years later, in 1934, the patient and her husband were divorced and later in 1934 the patient remarried. Another child was earnestly desired but the patient did not become pregnant in the next eight years. During these years menstruation was regular, lasted four days and was painless. Her last menstrual period began July 20, 1942 and lasted four days the amount being normal. She did not menstruate in August and believed that she was pregnant.

On September 8 the symptoms and signs of an acute abdominal condition appeared suddenly. Her husband, a chiropractor, summoned an osteopathic physician, who sent the patient to a small suburban hospital and operated on her at once. At operation an orange-sized cyst of the right ovary with a twisted pedicle and the accompanying tube were removed. No content with the surgical procedure, the left ovary and tube were also removed. Apparently the possibility of a pregnancy was not considered. Recovery was without incident.

In January 1943 the patient again consulted her osteopathic surgeon because of a large mass in the lower part of the abdomen. The cyst of the right ovary, the left ovary and both tubes were then located and sent to a competent pathologist, whose report stated that the ovarian cyst was of endometrial type, the other ovary being essentially normal. The tubes were normal. The patient was then advised to have roentgen treatment for supposed intra-abdominal endometriosis. The possibility of a pregnancy was apparently not considered even at this date.

The patient's prepartal course was normal. On March 13, 1943, a roentgenogram showed a fetus in utero with right occipital presentation and apparently normal development for the early part of the eighth month of gestation. A cesarean section was done on April 20, this date being considered to be seven to ten days prior to term. Operation revealed a sheet of omental adhesions was spread throughout the entire lower part of the abdomen, the bladder, the entire uterus to the posterior wall of the fundus and the lateral pelvic walls being completely covered. In view of the extent of the adhesions, no attempt was made to release them. The omentum covering the scar of the previous section was incised, and then the uterine wall, which was approximately $1\frac{1}{4}$ to $1\frac{1}{2}$ inches (3.2 to 3.8 cm) in thickness. When the uterus was opened, it became evident that a tumor involved the entire uterine wall of the fundus. The demarcation between the normal uterine wall and the tumor was easily identified. In addition, there was a fibroid the size of an apple near the cervix on the right lateral aspect and a smaller one nearby. A living female child was delivered and the placenta removed intact. Bleeding from the incised tumor was unusually free necessitating considerable ligation of individual vessels. The usual closure was done, and convalescence was entirely normal.

The patient has been amenorrheic since the cesarean section and has had the usual symptoms of surgical menopause, beginning about sixty days after the section and relieved by the use of ovarian hormones. From such data as are available from the statements made to the patient and her husband and from the pathologic report, it appears certain that both ovaries were excised completely at the original procedure for removal of the ovarian cyst. No effort was made to determine the presence of ovarian tissue at the time of the section because of the extensive adhesions. Likewise, a hysterectomy was not done, in view of the patient's request that such a procedure be not done at this time if it added to the risk. Such a policy was probably best in view of the unduly excessive hemorrhage from the incised wall of the uterine tumor and the necessity of releasing the firm, widespread adhesions. Examination one year after the section disclosed a uterus the size of two fists. The patient has declined to have further surgical treatment.

The patient's last menstruation began July 20, 1942, and the ovaries were removed on September 8. If one adds ten days to the date of the onset of menstruation, this gestation was of forty days' duration at the date of bilateral oophorectomy. If one adds fifteen days (instead of ten) as the most likely time of conception, then the duration of gestation was thirty-five days at the time of the bilateral oophorectomy. By either computation, the duration of the gestation was far less than the ninety days during which the ovarian hormone (progesterone) is believed to be necessary for the retention of pregnancy.

Seegar and Delfs³ reported a case in which a Negro woman of 26, who had four full term, spontaneous deliveries, was operated on on May 29, 1939, the left tube and ovary being removed. The only menstruation between the date of operation, on May 29, and the date

³ Seegar, G. E., and Delfs, E. Pregnandiol Excretion Following Bilateral Oophorectomy in Early Pregnancy, J. A. M. A. 115:1267 (Oct. 12) 1940.

of admission to the hospital, on September 12, had been on July 2. On the basis of the symptoms and findings, a tentative diagnosis of ectopic pregnancy was made.

On September 13 a cyst of the right ovary and the right tube were removed. The uterus was noted to be enlarged and softened, giving the appearance of a uterus of early pregnancy. Labor occurred spontaneously on March 26, 1940, fourteen days before the expected date of confinement, a normal female child being delivered by breech extraction. Thus, the pregnancy of this patient went practically to term, although all ovarian tissue was removed on the sixty-third day of gestation.

Values for pregnandiol throughout the course of the pregnancy in this case were unusually low, the cause of which could not be evaluated.

Young, stimulated by the report of Seegar and Delfs, made one determination of pregnandiol during the last month of pregnancy in his case, this determination gave values well within the limits of normal and seemed to prove conclusively that the placenta was producing most of the progesterone.

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DISCUSSION

DR THEODORE F RIGGS, Pierre, S D Before the estrogens were available, a married woman aged 23 reported to me with her first pregnancy. Examination revealed two firm masses, one on each side of the midline, and a third, softer mass in the pelvis. Her pregnancy was of less than four and a half months' duration, and I suspected dermoids with the pregnancy. On examination a few weeks later the two upper masses appeared to have grown more than the pelvic mass. While I realized the danger, surgical intervention seemed necessary. Operation revealed bilateral dermoids, which were removed as gently as possible. The pregnancy went on to an uncomplicated, spontaneous delivery, the placenta doubtless substituting for the ovarian tissue which had been removed.

RADICAL MASTECTOMY

Prognosis After Survival for Five Years

ARTHUR B McGRAW, MD

GROSSE POINTE, MICH

THIS paper is the report of an attempt to discover what happens eventually to women who have undergone the Halsted radical mastectomy and have survived five years or longer

Since the opening of its department of surgery, thirty years ago, 598 such operations have been performed at the Henry Ford Hospital, 412 of them up to the end of 1941, with a mortality rate of 22 per cent. As the result of an intensive follow-up study of all radically treated patients with cancer of the breast, begun in 1930 and carried on without interruption despite obstacles of the war years, my colleagues and I have current follow-up information on all but 6 of the 412 patients (table 1). By recent check, we find that 177, or 43 per cent, survived their operation five years and more. Of these 177 patients, we have lost track of only 2 (table 2).

Three main considerations led us to study these five year survivors and their subsequent fate. First was an experience, many years ago, of discovering that a half-dozen women previously reported rather confidently as "five year cures" had all died subsequently of late developing metastases. A second consideration was that the operations on the present group of patients were performed in a similar manner and by a small group of surgeons. The chief surgeon of the hospital, Dr R D McClure, performed 51 per cent of these operations, 4 other surgeons, another 41 per cent, while the remainder, 8 per cent, or 14 operations, were done by ten surgeons during their periods of training at the hospital. All operations, therefore, have conformed with the deliberately and thoroughly radical basic pattern established long ago by Halsted¹ and Meyer² and recently elaborated and illustrated by Haagensen³. The third consideration was a desire to discover either value or disadvantage in two or three variants in operative detail and postoperative treatment.

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1 Halsted, W S Surgical Papers, Johns Hopkins Hosp Rep 4 297-350,
1894-1895

2 Meyer, W Cancer of the Breast, Surg, Gynec. & Obst 24 553-577, 1917

3 Haagensen, C D A Technique for Radical Mastectomy, Surgery 19
1-131, 1946

A follow-up program, properly conducted, is a continuous, persistent process. When the fate of a group of patients with radical treatment for a particular kind of cancer is studied, so to speak, by stopping the clock at a given point of time, and after a predetermined interval, one is at once confronted with four mutually exclusive subgroups. There are the patients known currently to be living and apparently well, the patients known to have died of intercurrent disease and apparently free of recurrence, the patients known to have died with recurrence or

TABLE 1.—Data on Four Hundred and Twelve Patients Who Had Undergone Radical Mastectomy (1916-1941)

Patient Group		Current Follow Up Information	Completeness of Follow Up Information
Total number of patients operated on	412	408	97%
Patients surviving five years	177	175	97%

TABLE 2.—Data on Four Hundred and Twelve Patients with Radical Mastectomies (1916-1941) After Five Years

	Total Number of Operations	Five Year Survivors	
		Number	Percentage
All patients	412	177	43
Patients with axillary nodes involved	21	74	36
Patients with axillary nodes clear	161	103	64

TABLE 3.—Numerical Distribution of Subgroups of Patients (177) Surviving Radical Mastectomy Five Years or More

	Axillary Nodes Involved	Axillary Nodes Clear	All Patients
Patients living and well	30	70	100
Patients who had died of intercurrent disease	16	13	29
Patients who had died of or were living with cancer	23	20	48
All patients	74	103	177

metastases, and the patients known to be living with recurrence. Since the patients in the present series known to be living with recurrence number only 7 they have, for purposes of analysis, been added to the larger group, of 41, known to have died of metastases. Table 3 shows the numerical distribution of these subgroups in our series.

PATIENTS WHO HAVE DIED OF METASTASES OR ARE LIVING WITH RECURRENCE

I shall first consider briefly the subgroup of 48 patients known either to have died of metastases or to be living with recurrence. There are 41 of the former and 7 of the latter. Their ages at operation tend

to fall slightly above 50, a corresponding slightly greater number of the women past 50 having passed the menopause before operation. Sixteen (one third) of these 48 patients lived five years but less than six years after operation (table 4). Of the 32 (two thirds) whose period of survival exceeded five years, 13 lived longer than ten years. Thus, in the subgroup whose fate to die of or live with their cancer was sealed in spite of surgical intervention, there was achieved a ten year salvage of

TABLE 4—*Postoperative Periods for Forty-Eight Patients Who Survived Radical Mastectomy Five Years or More But Who Died of or Were Living with Recurrence*

Postoperative Period	Number of Patients	Percentage
Under 6 years	16	33
6 to 9 years	19	40
10 to 14 years	10	21
15 to 19 years	2	4
20 years or more	1	2
Total	48	100

TABLE 5—*Attainment of Life Expectancy of Forty-Eight Patients Who Survived Radical Mastectomy Over Five Years But Had Died of or Were Living with Recurrence*

Life Expectancy Attained	Number of Patients	Percentage
Less than one half	33	69
One-half or better	15	31
Full or better	8	6

TABLE 6—*First Appearance of Recurrence in Forty-Eight Patients Who Survived Radical Mastectomy Over Five Years But Who Had Died of or Were Living with Recurrence*

Period Before Recurrence	Number of Patients	Percentage
Under 5 years	20	42
5 to 9 years	20	42
10 to 14 years	6	12
15 to 19 years	1	2
20 years or more	1	2
Total	48	100

27 per cent. It may be noted in table 5 that 31 per cent had reached or exceeded half their life expectancy at the time of their operation.

We were greatly surprised to find how many years of apparent good health elapsed before signs of recurrence or metastasis first developed. As shown in table 6, metastases appeared between the fifth and the ninth year after operation in 42 per cent of the 48 patients, between the tenth and the fourteenth year in 12 per cent and during the fifteenth year or later in 2 per cent.

We have scrutinized our data on the 8 patients whose recurrence or metastases appeared ten or more years after operation without discovering any dependable clues to the extraordinarily protracted quiescence of their microscopic foci of cancer which remained after operation. The 8 patients were mostly middle aged, though there was a woman of 29 and another of 62. Of the 8, only 2 were operated on within a month after they had first noticed their growth, 2 others had the operation one year afterward. Four had involvement of axillary nodes, 5 had retraction of the skin or the nipple or of both. Three had roentgen treatment immediately after operation. Four had adenocarcinoma, 3, seirrhous carcinoma, and 1, medullary carcinoma. The only uniform factor in the clinical findings or in the treatment of these 8 women was primary operative closure of the wound without a skin graft. Only

TABLE 7.—Data on Twenty-Nine Patients Who Survived Radical Mastectomy Over Five Years But Who Died of Intercurrent Disease

Period of Survival	Number of Patients*	Percentage
Under 6 years	7	24
6 to 9 years	7	24
10 to 14 years	9	31
15 to 19 years	4	14
20 years or more	2	7
Total	29	100

TABLE 8.—Attainment of Life Expectancy of Twenty-Nine Patients Who Survived Over Five Years But Died of Intercurrent Disease

Amount	Number of Patients	Percentage
Less than one half	5	17
One half or better	24	83
Full or better	13	46

in a much larger number of patients would such a common factor have even conjectural significance.

The clinical, operative and postoperative data on these 48 patients who ultimately died of their disease were further analyzed, without discoveries of statistical significance. That there were in this group twice the number of patients with retraction of the nipple and deep fixation of the growth and distinctly more patients with retraction of the skin are findings to be expected. As to the types of cancer, there was a slight predominance of adenocarcinoma and an understandable absence of colloid growths.

PATIENTS WHO DIED OF INTERCURRENT DISEASE

The next subgroup of patients to be considered is that in which death occurred after five years from intercurrent disease and without known recurrence or metastasis. This group numbers 29 patients. It will be dealt with briefly, for death from intercurrent disease always

leaves uncertainty regarding the possible presence of undetectable remaining foci of cancer. Only 5 of this group died in this hospital, where direct clinical observation or autopsy could give confirmatory evidence. The survival periods of these 29 patients after operation are shown in tables 7 and 8.

In connection with their survival, it should be noted that 83 per cent of these women had lived over one-half their life expectancy at operation and 45 per cent had exceeded that expectancy, several from four to nine years. Had these older women been handled timidly by less than radical operation or by other than operative treatment, many of them would have died sooner, and of their cancer.

With regard to other clinical and operative data on this group, only one curious finding stands out. Eighty per cent had retraction of the

TABLE 9.—*Data on One Hundred Patients Who Survived Over Five Years and Were Currently Living and Well*

Postoperative Periods	Number of Patients	Percentage
Under 6 years	11	11
6 to 9 years	38	38
10 to 14 years	24	24
15 to 19 years	17	17
20 years or more	12	12
Total number	100	100

TABLE 10.—*Attainment of Life Expectancy for One Hundred Patients Surviving Over Five Years and Currently Living and Well*

Amount	Number of Patients	Percentage
Less than one-half	45	45
One-half or better	55	55
Full or better	17	17

skin over the tumor at the time of operation. This striking frequency of retraction of the skin seems most plausibly explained by the greater ease with which retraction of the skin can occur and be detected in the atrophic elderly breast. The neglect of their tumors by these patients before they sought operation was no greater than that shown in the other subgroups.

PATIENTS LIVING AND APPARENTLY WELL

The third subgroup to be considered is that of the patients known to be living and well five years or more after operation. It numbers 100 persons, a larger number by one third than the other two groups combined. In addition to being a larger group numerically, a greater proportion of these patients have survived long periods of years, as is evident from comparison of table 9 with tables 4 and 7. Fifty-five per cent of these patients have to date lived over one-half their life expectancy, and 17 per cent have exceeded it (table 10).

With regard to clinical findings, there is one outstanding difference in this group, which undoubtedly is the principal factor in the longer survival of its members. Only 30 of the 100 patients were observed at operation to have metastases in the axillary lymph nodes, almost an exact reversal of the situation in the group who died of or are living with cancer. Other characteristics of the tumors of this group, such as retraction of the skin, were also less frequent, though not notably so. There were a few less adenocarcinomas and scirrhous and medullary carcinomas and more duct carcinomas and the group contained two thirds of all tumors with colloid characteristics.

The data on the 12 patients of this group who have lived twenty years and over were examined to see whether their clinical and operative

TABLE 11.—*Primary Closure Versus Skin Grafting with Regard to Condition of Axillary Nodes*

Procedure	All Patients (177), Percentage	Patients with Axilla Clear (106), Percentage	Patients with Axilla Involved (71), Percentage
Skin grafting	52	25	41
Primary closure	68	75	59
	100	100	100

TABLE 12.—*Primary Closure Versus Skin Grafting with Respect to Survival Subgroups*

Procedure	Patients Living and Well (100), Percentage	Patients Who Died of Intercurrent Disease (29), Percentage	Patients Who Died of or Were Living with Recurrence (45), Percentage
Skin grafting	52	52	10.5
Primary closure	67	48	83.5
	100	100	100

observations gave an especially good theoretic prognosis of a long survival. Favorable factors were that one half had operations less than one month after noticing their tumor and that two thirds were free of axillary involvement. On the unfavorable side, it is to be noted that 6 of the 12 had scirrhous carcinoma, 4 adenocarcinoma and 1 medullary carcinoma, and 8 had some combination of retraction of the skin, retraction of the nipple or fixation to the thoracic wall.

EFFECTS OF MANNER OF CLOSURE OF THE WOUND

I now turn to two variants in operative procedure, clues to the advantages or disadvantages of which have been sought in this study. First is the manner of closure of the wound—primary closure versus partial closure, with immediate application of a split thickness graft to the defect. By reference to tables 11 and 12 it will be seen that

in nearly one third of the operations a graft was used and that it was used more often in cases with axillary metastases. Grafts were also used twice as often in the group of the patients who are living and well as in the group of the patients who have died of or are living with recurrence.

Table 13 indicates that there are definite differences in the time of wound healing in the cases with skin grafting and the cases with primary closure of the wound.

TABLE 13.—*Primary Closure Versus Skin Grafting with Respect to Effect on Time of Wound Healing in Series of One Hundred and Seventy-Seven Patients Surviving Over Five Years*

Time	Percentage of Patients	
	Skin Grafting	Closure
Under 1 month	4.5	11
2 months or less	72	62
3 to 4 months	21	18
5 months or over	7	20

TABLE 14.—*Primary Closure Versus Skin Grafting with Respect to Effect on Shoulder Motion and Edema of Arm for One Hundred and Seventy-Seven Patients Surviving More Than Five Years*

	Percentage of Patients	
	Skin Grafting	Closure
100% motion impairment	79 21	91 9
	— 100	— 100
Edema	56	59
No edema	44	41
	— 100	— 100

A split thickness graft rather dependably (in 72 per cent) secured healing in two months or less and rarely (in 7 per cent) resulted in greatly delayed healing. Although primary closure led skin grafting in cases in which healing occurred within one month (11 per cent), it also, by reason of the risk of sloughing of the wound edge, resulted in nearly three times (20 per cent) as many slowly healing wounds as did grafting. Table 14 indicates that more instances of impaired arm motion followed skin grafting than followed primary closure of the wound. There was no significant difference between grafting and primary closure in the incidence of postoperative edema of the arm. In recording the latter complication, minimal, and even transient, swelling was classified as edema.

apparently well had such biopsies, and represent numerically the largest single group in the series, make us feel that careful biopsies are at least not harmful, and we are currently continuing the practice

INFLUENCE OF POSTOPERATIVE ROENTGENOTHERAPY

Comparison of the results for those of the 177 patients who had early postoperative roentgenotherapy with the results for those who did not is inconclusive as to any clearcut beneficial influence of such treatment on the prognosis Table 17 indicates this We do not wish to imply, however, that early postoperative roentgenotherapy is either harmful or of no possible value Our patients to whom such treatment was given were not selected with sufficient consistency and impartiality to warrant conclusions, even had our figures seemed to show a trend in either direction In the series of 177 patients, the proportion of women with axillary involvement who received roentgenotherapy was considerably larger than that of the women who were free from such metastases

CONCLUSION

In conclusion, the close observation and study of our series of patients with cancer of the breast, and especially of those who survived operation five years or more has in every way strengthened our conviction that a thoroughly radical operation is the only procedure at present giving such patients a good chance of long survival We believe that such an operation should be undertaken whenever it can be performed with technical adequacy unless coexisting metastases are so advanced or widespread and the patient's expectancy of life is clearly so short as to make operation futile

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DISCUSSION

DR WILLIS D GATCH, Indianapolis Here is a study extending over thirty years, probably costing thousands of dollars, which is honest and of tremendous scientific value I know of no such thorough study of the end results of the operative treatment of cancer of the breast Dr McGraw has traced 99 per cent of all patients

The paper is so rich in facts that I cannot hope to discuss all of them These results confirm the fact established by other studies that the modern operation for cancer of the breast gives about 40 per cent of five year survivals Halsted had this percentage of survivals fifty years ago, and he operated, on the whole, on patients with more advanced cancer than those operated on today I believe that any surgeon who reports a much higher survival rate than 40 to 45 per cent either is not following his patients carefully or must have a pathologist who is very free in his diagnosis of cancer The last factor is an important one. The inexperienced pathologist is inclined to play safe, as they say, and make a diagnosis of cancer in doubtful cases

pregnancy, (5) general constitutional diseases, such as diabetes, and (6) the age of the patient

Although metastasis to the axillary lymph nodes is only one of the factors which may indicate the extent of the disease at the time of operation, I believe that it is one of the most important indications of the prognosis after operation because of the great influence that it has on the rate of survival. I believe, therefore, that in compiling statistical studies of survival rates for malignant disease of the breast, all cases should be divided into two main groups, those with and those without metastasis to the axillary lymph nodes at the time of operation.

The grade of malignancy is important in prognosis, because the higher the grade of malignancy the greater the probability of metastasis to the axillary nodes. In the series of carcinoma of the breast at the Mayo Clinic, it was found that 49.2 per cent, or nearly one half of all carcinomas of the breast, were of grade 4 malignancy and that of the cases of grade 4 malignancy metastasis to the axillary nodes was present in 84.1 per cent at the time of the operation. When the lesions of grade 3 and grade 4 malignancy were combined, it was found that metastasis occurred early in 81.7 per cent of carcinoma of the breast. This observation, again, emphasizes the seriousness of malignant disease of the breast in that the majority of the lesions are of a high grade of malignancy and present a high percentage of metastasis to the axillary nodes at the time of operation.

The importance of the presence or absence of metastasis to the axillary nodes at the time of operation is shown in a study of 6,149 patients who had radical mastectomy, 60.5 per cent of whom had metastasis to the axillary nodes at the time of operation. Of the patients who did not have axillary metastasis at the time of operation, or 39.5 per cent of the entire series, the percentage who lived three years or more after operation was 85, a proportion almost twice as large as that of the group with axillary metastasis, which was 45.3 per cent. For the five, ten, fifteen and twenty year survival periods of patients without metastasis to the axillary nodes, it was found that the rates showed progressive improvement as compared with the rates for the group with axillary metastasis. For the five year period, the survival rate for the group without metastasis was 75.7 per cent, and that for the group with metastasis, 30.4 per cent, for the ten year period the survival rates for the group without and the group with axillary metastasis were 57.9 and 16.4 per cent, respectively, for the fifteen year period, they were 44 and 11.1 per cent, and for the twenty year period they were 33.5 and 6.5 per cent.

DR. ARTHUR B. McGRAW, Grosse Pointe, Mich. I wish, first, to clear a possible misunderstanding with regard to my statement about roentgen treatment after radical mastectomy. What I had to say dealt entirely with immediate or early postoperative treatment. My colleagues and I use and depend greatly on high voltage roentgen therapy in the care of patients in whom metastasis develops and who later die of the metastases.

You might be interested in the sources of our follow-up studies, that is, how we came by our information. Briefly, in order of the frequency, they were as follows: (1) patients who either were seen alive at the Henry Ford Hospital or died in the hospital, total 48 per cent of the patients followed in this report, (2) information by letter which we considered adequate, 22 per cent, (3) information by telephone (which we did not like to use but had to to some extent), 11 per cent, (4) The board of health, either of the city of Detroit or of other

communities, 10 per cent, (5) physicians, 5 per cent, (6) verbal report, only 4 per cent.

In determining the adequacy of this follow-up information, we rated what we secured ourselves, what we got through boards of health and what we got from physicians as dependably accurate. Such information totals 63 per cent. We consider letters and carefully conducted telephone conversations as reasonably good reports, and information from these sources totals 33 per cent. What we should regard as questionable information only comes to 4 per cent of our total follow-up data.

I wish to thank Dr Gatch for his kind and interesting discussion. He went into a number of points that I should like to have mentioned, but which the time forbade. I am also grateful to Dr Harrington for bringing the two interesting lantern slides and giving you the benefit of what I believe is an important factor in the matter of follow-up studies. Such surveys not only have to be pursued and continued but must be well planned, and in any hospital of five hundred beds or more there ought to be a department of biometrics and statistics, as there is in the Mayo Clinic. In such a department, studies are first planned, then data collected and finally assembled and sorted. The information that proves irrelevant can be picked out and set aside, and the relevant data can be put on record, accumulated and finally interpreted with regard to its statistical significance.

When that is done, as at the Mayo Clinic, one possesses, as you have seen in Dr Harrington's lantern slides, a splendid resume. What are those of us who have numerically smaller groups of cases going to do? One wonders whether an organization such as this association might not undertake some form of planned cooperative follow-up study among its members. Certain types of lesions or conditions in which we were interested could thereby be followed carefully and uniformly over a period of years. By combining a number of small groups of cases, a single, large group yielding statistically significant information would be secured.

AMEBIASIS WITH PULMONARY INVOLVEMENT

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AND

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ENDAMOEBA histolytica, first described by Losch in 1875, has been long established as the cause of tropical liver abscess. The specificity of emetine hydrochloride in the treatment of amebic infection was established by Vedder and by Rogers.¹ Recent articles by Ochsner and DeBakey,² Smith and Ruffin³ and Klatskin⁴ have reemphasized the value, first recognized by Rogers,⁵ of emetine hydrochloride therapy in contrast to open operative drainage.

INCIDENCE

Endamoeba histolytica is probably harbored by between 10 and 20 per cent of the population, with twice this percentage in the returning soldiers from some areas. The incidence in these carriers of active dysentery is not accurately known. The incidence of hepatic involvement in cases of dysentery varies from 9 per cent in early, well treated clinical cases to 95 per cent in fatal cases. Pleural and pulmonary complications occur in from 5 to 15 per cent of cases of dysentery and in from 10 to 20 per cent of cases of hepatitis.

From the Thoracic Surgery Section, Kennedy Veterans Administration Hospital

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1 Rogers, L. The Rapid Cure of Amoebic Dysentery and Hepatitis by Hypodermic Injection of Soluble Salts of Emetine, *Brit. M J* 1 1424, 1912

2 Ochsner, A., and DeBakey, M. Amoebic Hepatitis and Hepatic Abscess, *Surgery* 13 460 and 612, 1943; Pleuropulmonary Complication of Amebiasis, *J Thoracic Surg* 5 225, 1936

3 Smith, C., and Ruffin, J. M. Amoebic Infection of the Liver as Seen in North Carolina, *Gastroenterology* 6 294, 1946

4 Klatskin, G. Amebiasis of the Liver Diagnosis and Treatment, *Ann Int Med* 25 601, 1946

5 Rogers, L. Amoebic Liver Abscess, *Lancet* 1 463, 1922

PATHOLOGIC PROCESS

Through the portal vein the ameba reaches the liver, in which thrombosis and necrosis first occur in the finer radicles. The process may be arrested with fibrosis or may extend and coalesce to form a typical large solitary abscess of the right lobe of the liver, usually anteriorly and medially. The pleura and lungs usually become involved by direct extension through the diaphragm. A sterile empyema, with bloody or reddish brown fluid, follows pleural involvement. Bronchobiliary fistula without empyema or pneumonitis frequently occurs. More often diffuse pneumonitis of the lower lobe of the right lung occurs, followed by an abscess or a bronchopleural fistula.

CLINICAL PICTURE

The initial clinical picture before pulmonary involvement is usually that of acute amebic hepatitis with or without abscess formation. The patient appears acutely ill, with chills and fever, pain in the right upper abdominal quadrant often referred to the shoulder and an enlarged tender liver. Roentgenologic study reveals elevation, irregularity and fixation of the right side of the diaphragm.

Klatskin, in a series of 69 patients with hepatic disease, found that abnormal pulmonary physical symptoms were present in 16 and that while a primary diagnosis of pulmonary disease was made in only 16 per cent of the entire series it was made in one third of the cases in which there was acute hepatitis or hepatic abscess. In 17 of the 36 cases the roentgenograms showed abnormalities which were usually interpreted as those of early pneumonia. The pulmonary changes were considered as secondary to the involvement of the liver and were thought to be probably due to atelectasis.

When the pleura becomes involved, cough and pain in the chest, aggravated by deep breathing, and an associated pleural effusion make their appearance. Aspiration of the pleural effusion usually reveals a sterile bloody or reddish brown fluid, in which amebas may be found.

When the lungs become involved, the initial dry irritative cough quickly becomes productive of a bloody purulent sputum, in which amebas may also be found. Roentgenograms of the chest usually reveal a characteristic fixed elevated diaphragm, with a localized bulging and obliteration of the cardiophrenic and anterior costophrenic angles and a characteristic triangular shadow with the base toward the liver and the apex extending toward the hilus of the lung. Cavitation may be present. After the abscess ruptures into a bronchus, the resulting bronchohepatic fistula may be demonstrated with iodized oil U.S.P. When pulmonary and hepatic amebic disease remains undiagnosed for a period of time, the patient loses weight and becomes weak and anemic.

In patients with these symptoms there is commonly moderate leukocytosis, without much change in the proportion of polymorphonuclear leukocytes. The sedimentation rate is elevated. Eosinophilia is unusual.

DIAGNOSIS

The most important factor in making the diagnosis is to consider the possibility of amebic infection. An infection with ameba should always be considered a possibility in a patient presenting an acute febrile illness with symptoms in the chest when the lesion involves the lower lobe of the right lung or the right region of the diaphragm or when a bloody pleural effusion is present.

A presumptive diagnosis can be made when there is an associated enlarged tender liver, a fixed elevated diaphragm and characteristic roentgenologic findings.

A positive diagnosis is reached by the characteristic response to emetine hydrochloride or by the finding of the causative organism, *E. histolytica*, in the sputum or aspirated fluid. A history of or the presence of dysentery is not essential to the diagnosis.

Diagnoses which are most commonly made when a patient has pleuropulmonary amebiasis are basal tuberculosis, a pyogenic abscess of the lung, carcinoma of the lung or liver, pyogenic subphrenic abscess, perinephritic abscess, pyogenic empyema, malaria, typhoid and dengue fever.

TREATMENT

The specific therapy for amebic hepatic and pleuropulmonary involvement is emetine hydrochloride given subcutaneously. The usually recommended dosage is 0.5 grain (0.03 Gm.) twice a day or 1 grain (0.06 Gm.) daily for six to ten days. Before the institution of this treatment, the patient should have thorough cardiovascular studies, including an electrocardiogram, since the drug is primarily a protoplasmic poison that first affects the myocardium. Toxicity is shown by lowering of the blood pressure and cardiac irregularity. An adequate diet of proteins, carbohydrates and vitamins is indicated.

A full course of emetine hydrochloride is given in the presence of an abscess before other measures are considered except when the abscess threatens rupture as shown by an increase in size. Aspiration of such an abscess by the method of Ochsner and DeBakey should be undertaken soon but preferably after two to four days of emetine hydrochloride therapy.

Klatskin has successfully treated several patients with hepatic abscess with emetine hydrochloride therapy alone. His criteria for cure are (1) complete absence of pain and fever, (2) absence of enlargement of the liver, (3) absence of subcostal and compression tenderness and

(4) a normal white blood cell count and sedimentation rate To achieve these results the dosage must be adequate, and an initial course of 12 grams (0.78 Gm) is given If necessary, subsequent courses of 1 grain (0.06 Gm) daily for six days are given, with two week periods of rest between courses The maximum dose required in any of his cases was 27 grams (1.75 Gm)

In addition to emetine hydrochloride, the use of either diodoquin or chiniofon is advisable In the presence of hepatic disease the arsenical amebacides such as carbarsone probably should not be used, but no known harm resulted from the use of this in the 3 cases reported here

Open drainage of amebic abscess is contraindicated, since Ochsner and DeBakey have shown that open drainage without the use of emetine

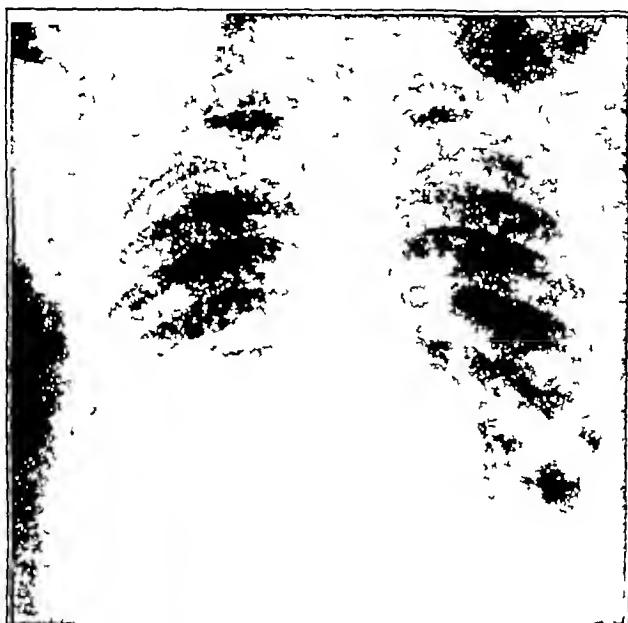


Fig 1 (case 1)—Roentgenogram shows the area of pneumonitis in the lower part of the right lung before treatment

hydrochloride gives a mortality rate of 48.2 per cent that open drainage with emetine hydrochloride gives a mortality rate of 15.3 per cent and that with emetine hydrochloride therapy alone the mortality rate is only 5.5 per cent Exceptions to this general rule should probably be made in the presence of abscesses secondarily infected from bronchial involvement and other causes which have not responded to treatment with emetine hydrochloride, penicillin and the sulfonamide compounds

Rogers stated that when emetine hydrochloride fails in superficially located abscesses of the left lobe of the liver surgical drainage is indicated since aspiration in these cases has proved hazardous

An amebic abscess of the lung should first be treated with emetine hydrochloride and penicillin or sulfadiazine. Usually the involvement clears with a minimal scarring. If cavitation persists or extends after

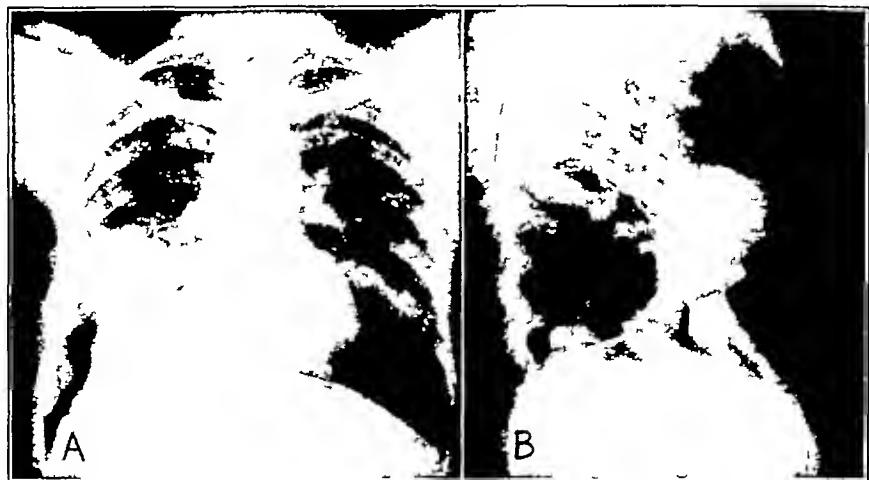


Fig 2 (case 1)—Roentgenogram of the same patient after pneumoperitoneum, showing adhesions between the liver and the diaphragm at the site of the pulmonary infiltration

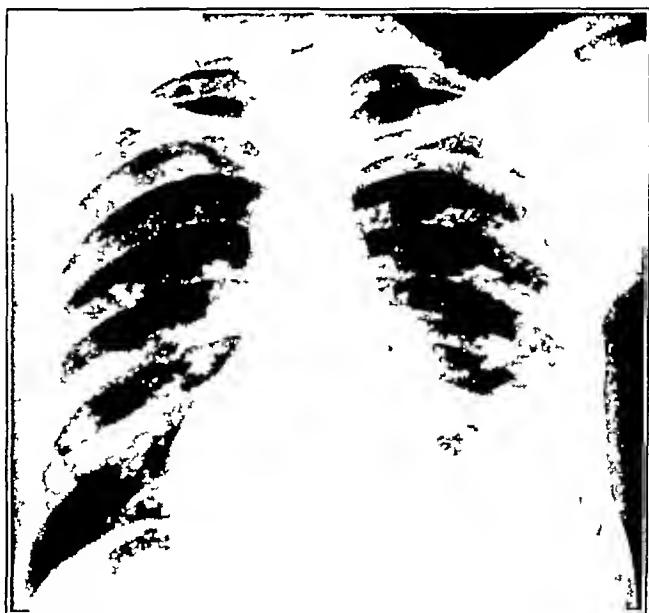


Fig 3 (case 1)—Immediate clearing of the pneumonitis after treatment with emetine hydrochloride daily for ten days

treatment, drainage is probably indicated. We have had no experience of nor have we found any reference in the literature to persistent cavitation of the lung due to the Endamoeba after adequate treatment with



Fig 4 (case 2).—*A*, roentgenogram of the chest on admission of the patient to the hospital with involvement of the lower part of the right lung. A bronchopleural fistula was present. *B*, the closed intercostal drainage tube in place, with clearing of the process.

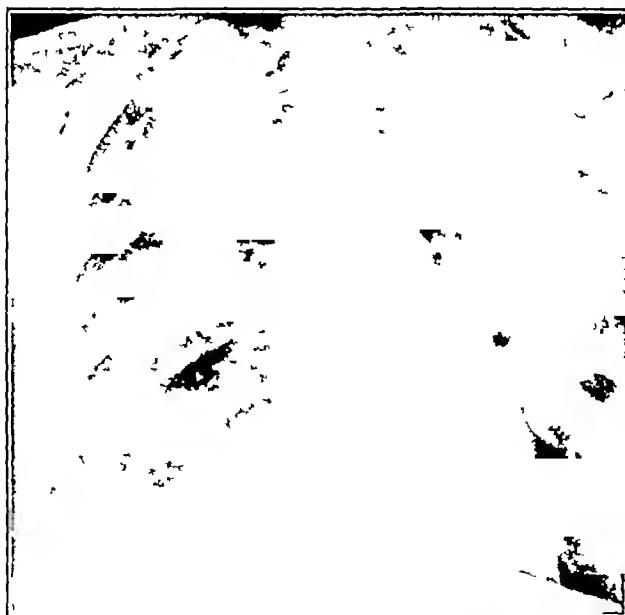


Fig 5 (case 2).—Residual scarring remaining after the use of emetine hydrochloride and closed drainage.



Fig 6 (case 3).—*A*, roentgenogram of the chest on admission of the patient to another hospital showing an amebic abscess of the lower part of the right lung. *B*, lateral view a few days later, with pneumonic involvement of the lower lobe.



Fig 7 (case 3).—The condition of the chest twenty-nine days after admission of the patient to Kennedy Veterans Administration Hospital. The patient on admission was toxic, had an open thoracotomy tube, a total empyema and a bronchopleural fistula.

emetine hydrochloride, but we feel that cases in which this occurs should be studied and the treatment should be the same as that in any undiagnosed cavitation of the lung.

Of our 2 patients at the Kennedy General Hospital and 1 at the Kennedy Veterans Hospital, 2 had empyema complicated by bronchopleural fistulas. One patient was treated with emetine hydrochloride, intercostal drainage and penicillin and recovered with a minimum amount of residual scarring of the lung. In the other a complete empyema, with a large bronchopleural fistula developed after open thoracotomy at another hospital. This patient was treated with emetine hydrochloride, closed intercostal drainage and decortication of the lung. More details of the 3 cases follow.

REPORT OF CASES

CASE 1 (figs 1 to 3) —In a 25 year old Negro cough, fever and pain in the right side of the chest developed in August 1944 while he was a patient at another hospital. A roentgenogram on September 26 revealed fixation of the right side of the diaphragm and an opacity in the lower lobe of the right lung. On October 18 he was admitted to Kennedy General Hospital. Bronchoscopy and a bronchogram were noncontributory. Pneumoperitoneum (fig 2) revealed adhesions between the liver and the diaphragm at the site of the pulmonary infiltration, and *E histolytica* was found in the stools. Emetine hydrochloride, 1 gram (0.06 Gm) subcutaneously, was given daily from November 11 to 21. The fairly pronounced clearing of the infiltration with descent of the diaphragm is shown in figure 3. A course of 120 grains (7.7 Gm.) of chiniofon and 8 grains (0.52 Gm.) of carbarsone was given before discharge of the patient from the hospital. On Jan 13, 1945, only a slight element of fibrosis with obliteration of the costophrenic angle, was present in the roentgenogram of the chest. The patient was discharged from the Army with a diagnosis of unqualified constitutional psychopathic state.

CASE 2 (figs 4 and 5) —Pain in the right lower part of the chest, nausea and vomiting, with weakness and loss of weight, developed in a 24 year old white man in May 1944. On June 24 his temperature was 103 F and he had a large tender liver. The roentgenogram of his chest is shown in figure 4A. Six days later, thoracentesis yielded reddish brown pus. With the development of a bronchopleural fistula, he suddenly expectorated large quantities of bloody pus.

He was admitted to Kennedy General Hospital on Sept 7, 1944, acutely ill and unable to lie flat in bed. Amebas were found in the pleural fluid at the time the intercostal closed drainage was instituted. Treatment with emetine hydrochloride was started the same day. Figure 4B shows the condition a few days later.

Two courses of emetine hydrochloride, carbarsone and vioform were given, and he was discharged sixty days after admission. He had gained 60 pounds (27 Kg.) in weight while in the hospital. Figure 5 shows the residual fibrosis at this time.

CASE 3 (figs 6 to 9) —A 21 year old white man became sick in May 1946 with pain in the right side of the chest and in the right shoulder, fever and weakness. Three weeks later a cough developed, with bloody purulent sputum. He was admitted to a hospital on June 11, 1946, with these symptoms and the demonstration

of a cavity and other typical findings in the roentgenogram (fig 6). The red blood cell count was 3,700,000, the hemoglobin content 75 per cent and the white blood cell count 10,800, with 78 per cent polymorphonuclear cells and 1 per cent eosinophils. Sterile bloody pleural fluid was aspirated two weeks after the patient's admission to the hospital. A month after admission, a thoracotomy was performed. Bloody fluid was found in large quantity. After this the pleural space was irrigated with chlorazodin or acriflavine or buffered aqueous solution of sodium



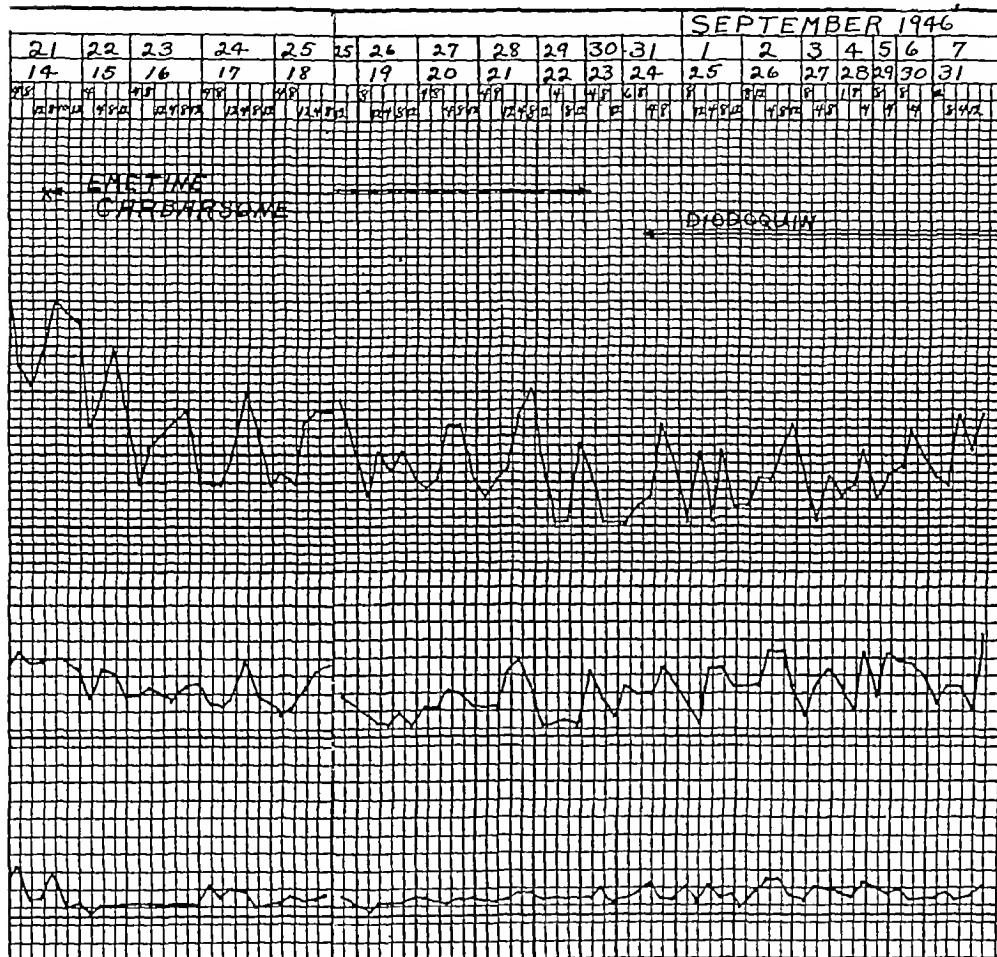
Fig 8.—The graphic chart during the first month at Kennedy Veterans A is shown. The change in the clinical condition was even more striking.

hypochlorite, and he was given penicillin and sulfonamide compounds, all without effect. On July 22, the right lung was collapsed, his red blood cell count was 2,500,000, and his hemoglobin content 50 per cent.

He was transferred to Kennedy Veterans Hospital on Aug 8, 1946, with the thoracotomy wound, empyema and bronchopleural fistula. There was tenderness in the right upper abdominal quadrant, and he had a daily temperature of up to 103 F. Culture of the fluid from the chest showed the presence of *Proteus*,

aerogenes, paracolon bacillus, *Bacillus pyocyaneus*, *Streptococcus* and *Staphylococcus*. A Stedman pump was used to obtain suction through a large intercostal tube.

The space was almost obliterated by displacement of the thoracic contents by August 17, but there was poor aeration of the lung, and the displacement could not be maintained (fig 6B). Bronchoscopic examination showed no pus, but a foul odor was present. The septic condition continued, and the serum albumin content



stration Hospital. The dramatic effect of emetine hydrochloride on the temperature

dropped to 2.5 Gm in spite of frequent blood transfusion and the intravenous administration of amigen. *E histolytica* was found in the pleural pus on August 21. Therapy with emetine hydrochloride and carbarsone was begun on the same day and was later followed by the administration of diodoquin.

The graphic chart (fig 8) shows the immediate response. By September 23 he had gained 10 pounds (4.5 Kg) in weight on a diet high in carbohydrate and protein. He had no fever for the first time in three months and the red blood

cell count was 4,500,000, the white blood cell count 13,000, the hemoglobin content 14.5 Gm per hundred cubic centimeters, the protein level and the albumin level 4.5 Gm.

Because of the persistent total collapse of the lung and the fistula, decortication and closure of the bronchopleural fistula with resection of a small portion of the lower lobe were done on September 24.

The fistula recurred, and the lung failed to expand completely. On November 7 a second decortication and closure of the fistula were done. The fistula remained closed, the condition on December 2, with the patient still under treatment, is shown in figure 9.



Fig. 9 (case 3).—Partially expanded lung after the first decortication. The bronchopleural fistula recurred.

SUMMARY

- 1 Three cases of amebic infection of the lung are reported.
- 2 The incidence of amebic infection in the United States is far more common than is realized.
- 3 Amebic hepatopulmonary disease occurs often enough to be included routinely in the differential diagnosis of diseases of the right upper abdominal quadrant or right lower part of the chest.
- 4 The diagnosis is made by the finding of *Endamoeba histolytica* or by the specific response to emetine hydrochloride.
- 5 Amebic infection of the liver and lung did not respond to any therapy until emetine hydrochloride was used.

6 Surgical procedures, apart from aspiration, are not indicated except for complications such as a total empyema or bronchopleural fistula.

7 Of our 3 patients, 1 responded to emetine hydrochloride; the second was cured by the administration of emetine hydrochloride and by closed drainage of an empyema and the third, in whom the condition was complicated by prior surgical treatment, required emetine hydrochloride and decortication.

TRAUMATIC BILIARY-BRONCHIAL FISTULA

With Report of Two Cases Due to War Wounds

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A BILIARY-BRONCHIAL fistula results from some disease or injury which establishes a communication between portions of the biliary and bronchial trees. Although of infrequent occurrence, such fistulas resulting from infection and abscess formation have long been recognized.¹ The most common immediate cause is infection of the subphrenic space, since this location is in close proximity to both biliary and bronchial tracts. If such infections spread upward via the lymphatic vessels through the diaphragm they may invade adherent lung tissue and eventually drain spontaneously through a bronchus. Bronchial fistulas are reported to occur in about 10 to 12 per cent of all cases of subphrenic abscess.² Similarly, suppurative lesions of the liver may drain via a bronchus after becoming adherent to the diaphragm in the absence of a true subphrenic abscess. Amebic abscesses and echinococcal cysts of the liver, especially when secondarily infected, may thus eventuate in a bronchial fistula. These two diseases appear to be the commonest causes of biliary-bronchial fistula,³ although Burgess⁴ and McNee⁵ believe the majority are due to suppurative processes in the biliary tract secondary to cholelithiasis. Blockade of the common duct from a variety of other causes, such as neoplasms, surgical trauma,

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1 Graham, J E Observations on Broncho-Biliary Fistula with Reports of Two Cases, Brit M J **1** 1397-1400, 1897

2 Ochsner, A, and De Bakey, M Subphrenic Abscess Collected Review and Analysis of 3,608 Collected and Personal Cases, Internat Abstr Surg **66** 426-438, 1938, in Surg, Gynec & Obst., May 1938 Head, J, and Hudson, T R Subphrenic Abscess with Bronchial Fistula, ibid **75** 54-60 (July) 1942

3 (a) Morton, J J, and Phillips, E W Broncho-Biliary Fistula Review of Recorded Cases Other than Those Due to Echinococcus and Amebic Abscess, Arch Surg **16** 697-754 (March) 1928 (b) French, R. W Bilio-Bronchial Fistula, ibid **30** 635-638 (April) 1935

4 Burgess, A H Bronchobiliary Fistula, Brit J Surg **9** 253-255 (Oct) 1921

5 Rolleston, H D, and McNee, J W Diseases of Liver, Gallbladder and Bile Ducts, ed 3, London, Macmillan & Company, Ltd, 1929

tuberculosis, gumma and parasites, may result in hydrohepatosis. Secondary or associated infection may then lead to involvement of the subphrenic space and an eventual fistula through the diaphragm and a bronchus. The blocked and dilated bile ducts thus offer an obvious explanation for the continuous expectoration of bile. One such fistula⁶ persisted for nine years. The essential pathologic changes necessary for the establishment of a biliary-bronchial fistula are therefore to be found below the diaphragm and consist of a lesion in either the liver parenchyma or the extrahepatic bile passages. The resulting sputum may contain bile mixed with other contents of a cavity, including purulent material, blood and necrotic liver tissue. Even biliary calculi have been reported in the sputum.¹ The term, bronchobiliary fistula, as found in the older literature,⁷ is a misnomer, inasmuch as suppurative processes above the diaphragm rarely, if ever, extend downward into the liver, the lymphatic flow being in the opposite direction.

In 1928 Morton and Phillips^{8a} reported a case and made a comprehensive survey of the literature on biliary-bronchial fistula. They recorded a total of 50 cases exclusive of those known to be due to amebic or echinococcic liver disease. In 1935 French^{8b} added to this collection. Since that time, several others⁸ have been reported which with the 2 cases herewith described, brings the total to 64. It is obvious that such fistulas are uncommon complications of nonparasitic liver disease. They are even less common as a result of trauma. Of these 64 cases, only 6, including the 2 we describe, have resulted directly from external violence or wounds. Our purpose is to review these 6 cases and to advance certain observations regarding pathology and treatment.

REPORT OF CASES

CASE 1.—History.—Pic G R P, white, American, aged 28, was wounded by a rifle bullet while on guard duty in France on July 9, 1944. The bullet entered the right anterior wall of the chest 2 inches (5 cm) medial to the nipple at the level of the fifth rib and emerged posteriorly in the midscapular line over the tenth rib. Ten hours later thoracotomy was performed at an evacuation hospital. Portions of the tenth and eleventh ribs were resected and the pleural cavity

6 Robson, A W M. Biliary Pulmonary Fistula Cured by Hepatodochotomy, Practitioner **75** 12-15, 1905

7 Graham¹ Morton and Phillips^{8a} Seelig, M G, and Singer, J J. Bronchobiliary Fistula, Arch Surg **19** 149-151 (July) 1929

8 (a) Sugimura, Y. Biliary-Bronchial Fistula, Ztschr d japan chir Gesellsch **36** 45-47, 1935 (b) Matrosov, S A. Biliobronchial Fistula, Vestnik khir **43** 100-103, 1936 (c) Martsinkovskiy, B I. Problem of Biliobronchial Fistula and Fermentative Capacity of the Liver, Klin med **16** 23-27, 1938 (d) Miller, I D. Broncho-Biliary Fistula Following Stenosis of Common Bile Duct, Brit J Surg **27** 425-426 (Oct) 1939 (e) Piccinini, P. Bilio-Bronchial Fistula Clinical and Roentgenological Study of Case, Ann Ital di chir **19** 589-606 (July-Aug) 1940

explored. Severe lacerations were sutured in the right lower pulmonary lobe and diaphragm. The chest was closed tightly and catheter drainage of the pleural cavity instituted through a counterincision. Following the operation his condition was fair, although he was dyspneic, with a sharp hacking cough productive of blood-streaked sputum. Three days after thoracotomy, aspiration of the right pleural cavity yielded 300 cc of bloody fluid and air. Roentgenograms on July 15 showed pneumothorax with fluid and about 10 per cent collapse of the right lung.

On July 18, nine days after being wounded, he first noticed a bitter tasting sputum, slight in amount at first, but increasing daily thereafter.

On July 23 he was transferred to the 297th General Hospital and was first seen by us. He complained of pain in the lower part of the right side of the chest and the upper abdominal area. He was dyspneic, with an irritating, persistent cough productive of a yellow bitter, blood-streaked sputum. He appeared anemic. Respirations were increased in rate and shallow. The lower part of the right side of the chest was dull to percussion, and the breath sounds were absent. The thoracotomy wound was unhealed and gaping in the posterior portion. The abdomen was soft but definitely tender over the area of the liver. The blood pressure was 108 systolic and 68 diastolic, the temperature 102.2 F., respirations 28 and pulse rate 104. Laboratory findings included red blood cells 3,210,000, white blood cells 20,040, hemoglobin 70 per cent. Urinalysis gave normal results. Examinations of the sputum was reported as yielding negative results with the tests for bile usually made on specimens of urine. Roentgen examination (fig 1) was reported by Lieut Col Elbert K Lewis as showing fluid in the right pleural cavity with 20 per cent compression of the lung. There was marked elevation of the right side of the diaphragm. The shadow of the liver was altered by an area of decreased density suggesting a tissue defect. A cloudy, serous fluid, 150 cc, was aspirated from the right side of the chest and a blood transfusion was given. The future course of this patient by dates was as follows:

Treatment and Course—July 26 He appeared improved. The cough was decreasing in frequency, but he was expectorating 4 to 6 ounces (118 to 178 cc) of yellow bitter mucoid sputum every twenty-four hours.

August 3 The patient had improved in the last eight days. About 4 ounces of sputum was generally raised per day, in one or two coughing spells. The temperature was 99.4 F., the pulse rate 108 and the respirations 22. The character of the sputum had suddenly changed to thin, yellow fluid resembling almost pure bile. Few blood streaks were present in it. The amount of sputum had increased to 8 ounces (236 cc) daily. Later in the day the patient complained of a burning sensation in the right side of the chest and had frank hemoptysis of about 80 cc of bright red blood.

August 4 Phrenic nerve crush was performed under local anesthesia through a right supraclavicular incision. This was decided on because of doubt as to whether the lung or the liver was the source of bleeding.

August 6 The patient's condition was greatly improved. The cough was decreased and he raised only about 2 ounces (60 cc.) in twenty-four hours, it was mucoid in character with few blood streaks and no gross evidence of bile. The patient was afebrile and pain was minimal.

August 8 He had a severe coughing spell with hemoptysis of 500 cc of blood, followed by a prolonged chill and a temperature of 104. Transfusions of whole blood and dextrose were given. Artificial pneumothorax was attempted, but was unsuccessful. No conclusion was reached as to the source of the hemor-

rhage, but it was believed to be probably of hepatic origin. At one time the patient complained of pain and tenderness in the lower right quadrant of the abdomen, and there was some rigidity suggesting the possibility of biliary leakage into the peritoneal cavity. These symptoms subsided in twenty-four hours.

August 9 Repeated and more severe hemoptysis of 900 cc of blood occurred. Transfusions of whole blood were given. The patient's condition was serious. Physical findings were about the same, although there was less clinical and roentgen evidence of fluid in the right side of the chest. Abdominal tenderness over the hepatic area was more marked. It was now felt that the limit of conservative treatment had probably already been overstretched and that death from

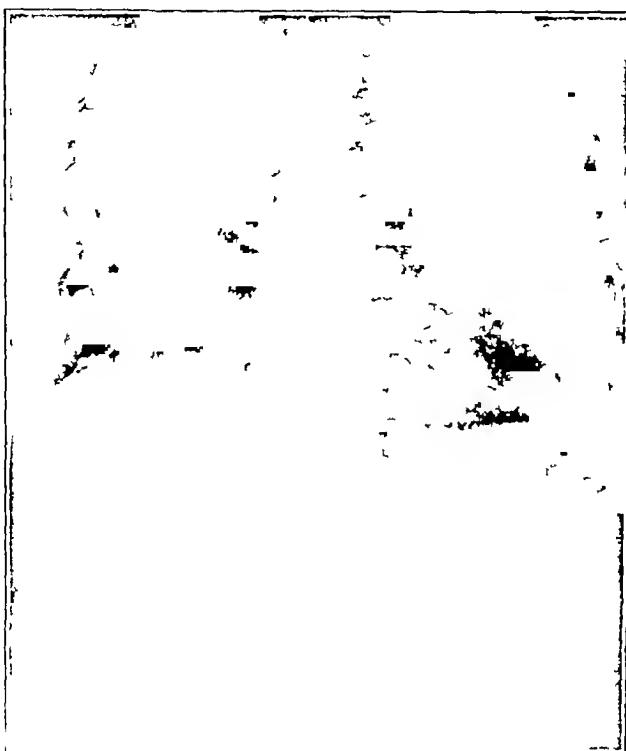


Fig 1 (case 1)—Roentgenogram taken July 24 shows 20 per cent pneumothorax with fluid and partial resection of right tenth and eleventh ribs. Decrease in density in the liver shadow was proved at operation to be a large necrotic cavity, due to trauma by bullet. Tract of bullet shown by irregular line extending downward and laterally in the liver shadow.

exsanguination was imminent unless the hemorrhage could be checked by surgical means.

August 10 Operation was performed for bleeding biliary-bronchial fistula. Capt. E R Donahue induced intratracheal nitrous oxide oxygen-ether anesthesia but only with great difficulty because of the poor condition of the patient and the constant bleeding into the bronchial tree. The right pleural cavity was entered through a posterolateral thoracotomy incision with removal of about 10 inches (25 cm) of the ninth rib. The lower pulmonary lobe was carefully freed of semifirm adhesions between it and the wall of the chest and diaphragm. Adhesions were particularly

firm around a defect in the lateral medial portion of the diaphragm measuring about $3\frac{1}{2}$ by $1\frac{1}{2}$ inches (9 by 4 cm) in size. Through this defect the fingers could be inserted into a large cavity at least 4 inches (10 cm) in diameter in the right lobe of the liver. The subdiaphragmatic space appeared well walled off by adhesions. The cavity was filled with necrotic yellow-brown hepatic tissue and blood clots old and recent, and bleeding was constant from it. A fist-sized mass of blood clots and necrotic tissue were easily scooped from this cavity, but the bleeding from it became so alarming that no attempt was made to empty it completely. On the diaphragmatic surface of the lung there was a necrotic depression approximately 2 inches (5 cm) in diameter and 1 inch (2.5 cm) deep. An open bronchus about 6 mm in diameter was clearly visible in the wall of this cavity. A wedge-shaped segment of lung including the cavity was resected and the defect closed with black silk sutures. The bronchial opening was closed by separate sutures. Bleeding from the liver was controlled by firm packing with about 12 yards of 3 inch (7.5 cm) dry bandage gauze. The thoracotomy wound was closed at both ends, leaving the center open for access to the liver cavity and for drainage. Extensive pleural adhesions made any marked pulmonary collapse unlikely. The patient's immediate postoperative condition was extremely poor although blood transfusion was continued during and after operation.

August 11 (second postoperative day) The patient was coughing moderately and raised blood-streaked sputum. No bile was visible in the sputum, and its bitter taste was gone. The dressings were saturated with a copious bloody yellow discharge.

August 16 (seventh postoperative day) The packing in the liver had not been disturbed. On this day a sudden hemorrhage of about 500 cc of blood occurred from the incision in the chest. The packing in the liver was reenforced, and a tight surface dressing was applied. The temperature was 101.6 F., the pulse rate 130 and the respirations 28. Cough was slight. The main complaint was pain in the upper right quadrant of the abdomen.

August 21 (twelfth postoperative day) All packing was removed. Through the thoracotomy one could look directly through the hole in the diaphragm into a portion of the liver cavity. The portion visible appeared to be lined by healthy granulation tissue, and there was no fresh bleeding. A sterile tray, with gloves, long forceps, gauze pack and dressings, was kept at the patient's bedside, and this was found to be a valuable forethought.

August 22 A sudden severe hemorrhage occurred from the liver, with a loss of an estimated 1,000 cc of blood. Also extruded was a large soft brown mass of necrotic liver tissue, 10 by 3 by 2 cm in size. The hemorrhage was promptly checked by rapid repacking with many yards of 4 inch gauze. During each of these repacking procedures the patient complained of only a moderate amount of pain, controllable by morphine.

August 28 For a week the patient had been comfortable, eating well and with no cough. Much clear bile still stained the dressings. On this date a third hemorrhage of approximately 1,000 cc. occurred suddenly. The old pack was removed and another inserted. It was noted that the liver cavity appeared 50 to 60 per cent smaller than at the operation, and the defect in the diaphragm was also greatly reduced in size.

September 6 Most of the packing had been extruded into the pleural cavity. All of it was removed. The defect in the diaphragm and liver now appeared as a shallow ulcer. The discharge was reduced in amount and there was no fresh bleeding.

October 10 By this date all drainage had ceased, and the thoracotomy wound was healed, the patient felt well and was up and about (fig 2)

November 22 The roentgenogram (fig 3) shows complete reexpansion of the right lung and healing of the liver defect. The patient was transferred in excellent condition to the United States. Two months later he wrote that he felt well and was able to do heavy work.

Other Therapy During treatment the patient was also given the following medicaments, whole blood and plasma

Penicillin, total amount	1,890,000 units
Sulfadiazine, total amount	42 Gm
Whole blood, total amount	7,650 cc
Plasma, total amount	3,000 cc

Summary—The patient had a thoracoabdominal perforating bullet wound on the right side. After nine days a biliary-bronchial fistula developed. After twenty-four days he began to have severe hemoptysis. After thirty-one days the biliary-bronchial fistula was excised through a transthoracic approach, and a bleeding necrotic cavity in the liver was treated by repeated packing. Full recovery occurred.

CASE 2—History—Pvt M S, aged 25, suffered a perforating bullet wound of the upper part of the left arm on July 4, 1944. About one hour later he was again wounded by a mortar shell fragment which entered the anterior part of the right side of the chest at the level of the second rib in the midclavicular line. Examination later showed this fragment to have passed through the right lung and diaphragm and lodged in the liver. After four hours the patient reached an aid station, where his wounds were dressed and plasma administered. On July 5 at an evacuation hospital the wounds were debrided and 600 cc of blood aspirated from the right pleural cavity. On July 14 he was transferred to a general hospital, where the right side of the chest was aspirated of 400, 500 and 540 cc of blood on the following three successive days. He was dyspneic and had continued to have a low grade fever since July 5. He also complained of severe pain in the upper part of the left arm, and there was evidence of a lesion of the median nerve, for treatment of which he was transferred to a neurosurgical hospital.

Treatment and Course—On July 21 he was admitted to the 55th General Hospital on the surgical service of Lieut. Col Joseph Roberts. At a later date, one of us (E T O) saw this patient, and Colonel Roberts gave us permission to report the case. A diagnosis was made of severe causalgia of the left median nerve, and this was relieved by blocking of the stellate ganglion.

On July 26 sympathectomy was performed on the second and third dorsal ganglia after excision of a portion of the fourth rib. Exploration of the ulnar and median nerves of the upper part of the left arm was done on August 7. From July 21 to August 19 the symptoms in the chest were quiescent, but on the latter date, forty-five days after wounding, he complained of pain and tenderness in the right upper quadrant of the abdomen, and his temperature rose to 101. A roentgenogram (fig 4) taken on August 22 showed the right side of the chest apparently clear, but an area of decreased density with a fluid level was noted below the diaphragm. This appeared to be well above the foreign body and was interpreted as evidence of a gas-containing intrahepatic abscess. Penicillin and sulfanilamide therapy was started, but his condition grew worse.

At operation, August 22, the right anterior subphrenic space was opened through a small subcostal incision, and about 600 cc. of bile-stained purulent material



Fig 2 (case 1)—Drawing made September 10, thirty days after repair of biliary-bronchial fistula and packing of bleeding necrotic cavity in liver. Scarring of the right posterolateral wall of the chest due to bullet wound and two thoracotomy incisions. A small central opening persists in the second incision



Fig 3 (case 1)—Roentgenogram taken November 22 shows resection of the ninth rib at the second operation, complete reexpansion of the right lung and irregularity of the right side of the diaphragm. The previous defect in the liver is not visible

was evacuated. A 22 F catheter was inserted for drainage. During the following week the patient was much improved and the temperature was normal. The drain was removed on August 30. On September 4 the temperature again rose and on September 7 the patient suddenly coughed up about 500 cc of foul-smelling, bile-stained purulent material. This was the first evidence of a biliary-bronchial fistula and appeared sixty-four days after the thoracoabdominal shrapnel wound. The cough persisted, with bile-stained sputum, and was very irritating. The patient complained of the bitter taste of the sputum. On September 8 the old incision was reopened and from the subphrenic space again drained a small amount of mixed pus and bile. For the next eleven days the patient continued to have a distressing cough productive of small amounts of bile-stained purulent sputum. A low grade fever persisted, and his condition gradually grew worse.

On September 19 a third operation was performed. Through a right rectus incision the anterior subphrenic space was more thoroughly explored and an abscess cavity measuring 3 by 2 inches in size was found in the liver. A 2 by 1 cm

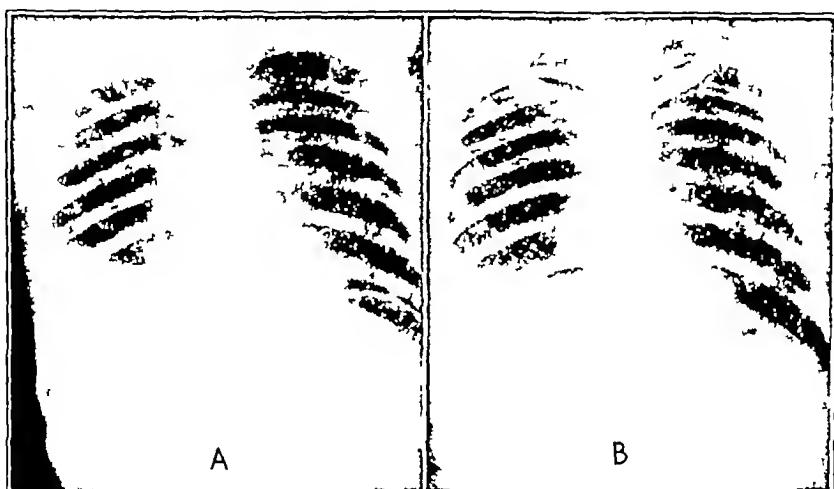


Fig 4 (case 2).—*A*, a roentgenogram was taken on August 22, forty-eight days after the patient received a thoraco-abdominal wound on the right side. A foreign body is visible in the liver. The cavity with fluid level interpreted as intrahepatic. Partial excision of the left fourth rib was performed for sympathectomy, to relieve causalgia of the median nerve following bullet wound in the left upper arm. *B*, a roentgenogram was taken on October 9 ninety-five days after wounding of the patient. A cavity is still visible in the liver area. There are evidences of scarring in the right lower pulmonary lobe, of diaphragmatic pleural adhesions and of fluid in right pleural cavity. The biliary bronchial fistula had closed spontaneously by this date, after drainage of the subphrenic space and liver abscess, and removal of the foreign body.

metallic foreign body was removed from the cavity and cigarette drains inserted through the incision, which was then closed around the drains. The patient's cough markedly decreased, as did the amount of sputum. By October 7 cough and expectoration had completely ceased. The biliary-bronchial fistula had closed spontaneously after persisting for thirty days. A roentgenogram (fig 5) taken on October 9 revealed more definite evidence of a pathologic process in the chest with a cloudiness in the right lower pulmonary field. A wedge-shaped shadow resembling pleural adhesions extended upward from the inner aspect of the dome

of the diaphragm. The gas-containing cavity was still visible. At this time there was another rise in temperature to 102 F., with clinical evidence of fluid in the right pleural cavity. Aspiration of the chest was not done. On October 11 the subphrenic space was again opened through the rectus incision. A moderate amount of pus was evacuated; a large catheter was introduced for drainage, and the incision was only partially closed. Daily saline irrigations were introduced through the catheter.

By November 1 the patient had been afebrile for two weeks, had gained 15 pounds (6.8 Kg.) in weight and felt well. His further progress toward recovery was uneventful.

Summary—The patient had a thoracolumbar shrapnel wound on the right side with hemothorax and a metallic foreign body in the liver. After forty-nine days there was evidence of liver abscess. After sixty-four days a biliary-bronchial fistula occurred. In ninety-four days the fistula had closed, after four operations for drainage of abscess of the subphrenic space and liver and removal of an intrahepatic foreign body. The patient recovered.

REVIEW OF THE LITERATURE

Graham¹ in 1897 reported the case of a man in whom the right anterior wall of the chest was injured when kicked by a horse. Seventeen days later he coughed up bile, but there was no expectoration of blood. Two operations were performed for drainage of the right pleural cavity which contained bile, but no mention is made of treatment directed toward the biliary-bronchial fistula. The patient made a slow recovery.

Tyrman² in 1909 cited a case due to a gunshot wound. The missile entered in the right nipple line over the fifth rib and emerged in the midscapular line posteriorly between the ninth and tenth ribs. The wounds were of a sucking type and were treated by packing. One week later the dressings were bile soaked and there was necrotic hepatic tissue in the drainage. Bile was expectorated in the sputum. Thirty-four days after wounding the chest was opened by resection of the fifth and sixth ribs in the axillary line. A finger-sized strand of tissue containing the fistula caused adhesion of the diaphragm to the lung. This was freed and a large wedge-shaped cavity with thick connective tissue walls was found in the region of the fistula. Drainage of the chest was instituted. The patient improved and the wound was closed twenty-two days later.

Elliott and Henry¹⁰ in 1916 reported a case of a soldier in whom an infected hemothorax developed after a shrapnel wound of the left side of the chest. Some days later the sputum became bile streaked, and on the twenty-sixth day after the patient was wounded an empyema

² Tyrman T. Ein Beitrag zur Kenntnis der Gallenerung-Bronchusfistel, Arch f Klin Chir 89:434-450, 1909.

¹⁰ Elliott T. R., and Henry H. G. M. A Case of Chole-Hemothorax, Brit M J 1:9 (Jan 1) 1916.

cavity on the left side of the chest was drained surgically. The expectoration of bile continued for ten weeks, and during this period the patient coughed up one or two fleshy masses of necrotic liver tissue. The empyema closed in fourteen weeks, after which the patient made a rapid recovery. No mention is made of hemoptysis or of roentgen findings.

Loe and Loe¹¹ in 1930 reported the case of a 12 year old boy who fell into a well and suffered a penetrating wound of the right posterior wall of the chest with fracture of the right eighth rib. During the next four days the clinical course and physical findings suggested the diagnosis of a septic hemothorax on the right side. The child coughed considerably, with bloody expectoration. Thirteen days after the injury the sputum appeared yellow, and the patient complained of its bitter taste. Four days later aspiration yielded thick pus and a small amount of blood from the right side of the chest. Under local anesthesia a portion of the right ninth rib was resected, and old clotted blood and pus were evacuated from the pleural cavity. A thumb-sized adhesion extended upward from the dome of the right leaf of the diaphragm to the collapsed lung. When this connection was severed a profuse flow of bile was noted. Rubber tube drainage of this biliary fistula and of the chest was instituted. Coughing decreased after operation, and the expectoration of bile stopped immediately. Drainage of bile from the wound ceased in five days. The patient made a satisfactory recovery and a roentgenogram of the chest showed that it was normal five months later.

In 1913 Stumpff¹² recorded a case of long-standing biliary tract disease in which diaphragmatic pleurisy developed. This was aggravated when the patient was knocked down by a bicycle. Three days later expectoration of bile occurred. Death resulted ten weeks later, and autopsy showed obliteration of the common bile duct with a biliary-bronchial fistula involving it and the duodenum. It is doubtful if the fistula in this case can be attributed to trauma.

In view of the frequency in wartime of combined thoracoabdominal wounds involving both liver and lung, it is perhaps surprising that so few cases of traumatic biliary-bronchial fistulas have been reported. That this is not due to an excessive and early mortality rate is borne out by G Gordon Taylor's¹³ statistics that 70 per cent of patients with abdominothoracic wounds on the right side survive, and 50 per cent of those with similar wounds on the left side. Wounds of the liver are usually either rapidly fatal from hemorrhage or else heal surprisingly.

11 Loe, A O and Loe, R H. Bronchobiliary Fistula, *S Clin. North America* **10** 1109-1117 (Oct.) 1930.

12 Stumpff, J E. Een geval van bilo-pulmonaal fistel, *Nederl tijdschr v geneesk.* **1** 232-236, 1913.

13 Maingot, R, Slesinger, E S, and Fletcher E. *Abdominal Injuries of Total Warfare, in War Wounds and Injuries* London Edward Arnold & Co 1937

well. It is well known that portal blood and liver tissue harbor bacteria which may be pathogenic but there is no evidence that wounds of the liver per se show any particular tendency to become infected. Elliott and Henry¹⁰ report that in a study of approximately 500 wounds of the chest, many with associated hepatic damage, there were only two external biliary fistulas, both of which closed spontaneously within thirty days. It would seem, therefore, that when wounds of the liver become septic they are apt to do so as a result of retained foreign material or from sizable fragments of liver tissue which become necrotic as a result of loss of blood supply. One of us (C C G) has, on numerous occasions, observed bullet paths through the liver at autopsy. If death has occurred several days after the wound is incurred the tract of the missile through the liver is lined by a yellow or yellow-brown zone representing bile-stained necrotic liver cells often surrounding a central small zone of hemorrhage. These necrotic cells are readily absorbed or walled off by granulation tissue, the recuperative power of the liver being remarkable. These granulations are replaced by scar tissue which readily blocks off the thin-walled compressible bile capillaries. If bile is to continue to escape from opened ducts or radicals, certain other pathologic features must exist. The intraductal biliary pressure may be elevated, and this undoubtedly is one explanation for the cases¹⁴ of biliary-bronchial fistula which have followed surgical operations on the extrahepatic bile passages. If necrotic liver tissue exists, an abscess cavity may result with widespread opening of numerous bile ducts. In such cases the expectoration or drainage of the necrotic tissue is not surprising. With this type of pathologic process it would seem that the opening of numerous blood vessels should also occur if the bile channels are opened, and hemoptysis would result. Yet only in our case 1 has hemorrhage been an outstanding feature. We may conclude that biliary-bronchial fistula will continue to be an infrequent sequence of injuries to the liver since the factors necessary for its development usually either do not exist, or if present lead to early death from hemorrhage or sepsis. This perhaps accounts for the fact that these fistulas are either not mentioned¹⁵ or are but briefly discussed¹⁶ in some of the recent textbooks on disease of the chest and thoracic surgery. In the latter references no mention is made of a traumatic causation.

The pathologic symptoms and findings in biliary-bronchial fistula were discussed by Morton and Phillips,^{8a} who noted that the first

14 French^{8b} Matrosov^{8b}

15 Sauerbruch, F., and O'Shaughnessy, L. Thoracic Surgery, London, Edward Arnold & Co., 1937

16 Cooke, R. Diseases of the Chest, Edinburgh, E & S Livingstone, 1944
Graham, E A, Singer, J J, and Ballou, H C. Surgical Disease of the Chest, Philadelphia, Lea & Febiger, 1935.

recorded cases were described by Mandard in 1854. The pathologic process must include adhesions between the liver and the diaphragm as well as adhesions between the diaphragm and lung. A potential cavity must originally exist either in the liver as an abscess, or in a walled off subphrenic or intrathoracic space. Large or dilated bile ducts and bronchi must both communicate with this space to form a fistula. The fistulous tract must have walls firm enough to prevent their collapse and closure by debris. The commonest location of the fistula is over the dome of the right lobe of the liver,⁹ connecting with the posterior or lateral portion of the right lower pulmonary lobe. Fistulas through the left side of the diaphragm and left lung have been reported. The lining and walls of the bronchial tree show a surprisingly slight reaction to the bile.

Symptoms and findings in cases following trauma are usually those of hemothorax or of empyema in the early stages. The nature of the injury is such that trauma to the liver may be presumed. With the appearance of bile in the sputum the patient complains of a persistent and irritating cough. The quantity of bile expectorated may vary from barely enough to tint the sputum to 1,200 cc daily. With it may be found blood in liquid or clotted form, debris and necrotic bits of liver tissue. The bile should be identifiable by the usual laboratory tests, but in our case 1 no conclusive positive results could be obtained by Obermayer's reagent or the nitric acid test. The reaction of the sputum is alkaline, which distinguishes it from that due to vomitus.

In these 6 cases 4 were clearly due to a combined thoracoabdominal bullet or shrapnel wound. In the case due to a kick by a horse we surmise that there were both pulmonary and hepatic injuries. The symptoms and findings in the traumatic cases should include evidences of injury both above and below the diaphragm. An apparent enlargement of the liver may be due to downward displacement of this organ from pressure by a subphrenic abscess but this may be compensated by paralysis and elevation of the diaphragm. If the fistulous tract through the lung is small, there need be but little if any evidence of a pulmonary pathologic process on physical examination. Roentgen examination may reveal the pathologic area partially or completely, as it did in the early stage of our case 1 and in the later stage of case 2. Evidence of consolidation at the base of the lung or immobile diaphragm and some defect in the contour of the dome of the liver are to be sought. If the hepatic or subphrenic abscess is partly evacuated, a fluid level may be seen in it.

The diagnosis is obvious with the appearance of bile in the sputum although if the patient is jaundiced the expectorated secretions may be yellow in the absence of a true fistula. In our case 1 as much as 250 cc

of clear bile was expectorated daily and a great deal more was mixed with blood. The patient volunteered that the expectoration had a bitter taste "like bile."

Laird and Wilkerson¹⁷ and Razemon¹⁸ have described how the diagnosis can be made by bronchoscopic injection of iodized oil. This procedure should also be of value in determining the extent of the pathologic process even if it were not necessary for diagnostic purposes.

TREATMENT OF BILIARY-BRONCHIAL FISTULA

The treatment of biliary-bronchial fistula must be based on considerations of causation, duration and progress of the clinical findings and extent of the associated pathologic process. The prophylactic treatment is almost entirely a matter of the proper early treatment of thoracoabdominal wounds. This has now been fairly well established as a result of the accumulated war experiences of many surgeons and is adequately described in a recent article by Snyder¹⁹. He discusses the value of a transthoracic approach and advocates the subdiaphragmatic drainage of wounds of the liver when necessary through a separate subcostal or loin incision after tight closure of the diaphragm. He recognizes that fatal hemorrhage may occur from wounds of the liver that have not been packed or sutured, but believes that drains should never be brought out through the pleural cavity. This is unquestionably the choice of procedures in fresh wounds, but it is not applicable to late cases, as illustrated by case 1. When a biliary-bronchial fistula makes its appearance, regardless of the type of original wound or of the early surgical procedures, it becomes obvious that the essential pathologic condition contributing to this fistula is in the liver. Three courses of treatment then suggest themselves. The first is to do little or nothing in the hope that nature will effect a cure. Spontaneous recovery can be expected in about 50 per cent of cases,²⁰ but may result only after a prolonged and debilitating illness, during which time other serious complications are to be feared. A conservative program was followed in case 1 until the severe and repeated hemorrhages made it apparent that the patient would die of exsanguination without radical surgical aid. In less severe cases, crushing of the phrenic nerve and pneumothorax therapy might be of some help, but they were of no value to this patient, and it is difficult to believe that much could be expected of such measures when the essential pathologic process is in the liver.

17 Laird, W. R., and Wilkerson, W. V. Biliary-Bronchial Fistula. First Recorded Case Demonstrated by Lipiodol, *Am. J. Surg.* **15**: 317-320 (Feb.) 1932.

18 Razemon, P., Bizard, G., and Lambret, M. Biliary-Bronchial Fistula, Following Lithiasis with Report of a Case, *Rev. de chir.*, Paris **52**: 485-505 (July) 1933.

19 Snyder, H. E. The Management of Intra-Thoracic and Thoraco-Abdominal Wounds in the Combat Zone, *Ann. Surg.* **122**: 333-357 (Sept.) 1945.

The second method of treatment is to establish drainage of the subphrenic space and liver abscess without disturbing the lung. Morton and Phillips^{3a} recommended this method of treatment, using local anesthesia and entering the subphrenic space through the diaphragm below the pleural reflection. They argued that this approach avoids the danger of pneumothorax and infection of the pleural cavity and that adhesions in the subphrenic space prevented peritoneal contamination. The subdiaphragmatic approach was employed in case 2 but repeated operations were necessary to establish adequate drainage. Entrance into a liver abscess through the subphrenic space is not easy if that space is obliterated by dense adhesions, as it may be if the disease is of considerable duration. This approach does not facilitate closure of the opening through the diaphragm.

The third method of attack is through the pleural cavity and it would appear to be the one of choice in the majority of such cases. This permits the lung to be freed from the fistulous opening in the diaphragm, after which the bronchial fistula may be closed. It allows exploration of the lower pleural cavity and drainage of any pockets of pus, blood or bile. Through this approach it is possible to enlarge the fistulous opening in the diaphragm and to explore the subphrenic space and underlying hepatic lobe. It permits the evacuation and packing of a cavity in the liver and, as illustrated by case 1, such a cavity may be repacked at frequent intervals if necessary. The objections to this approach are that it may open up uninfected areas of the pleura, and that it produces an open pneumothorax with consequent pulmonary collapse of some degree. These objections in our opinion are not of sufficient importance to outweigh the obvious advantages.

SUMMARY AND CONCLUSIONS

Four cases of biliary-bronchial fistula due to external violence have previously been described. We add two more, making a total of only 6 reported so far. These apparently have all resulted from combined thoracoabdominal injuries, 4 of them being due to bullet or shrapnel wounds. An explanation is suggested for their rarity in view of the large number of wartime injuries of this nature. The essential pathologic process is in the liver, and effective surgical therapy must be primarily directed to this organ. A transthoracic approach is recommended for closure of the bronchial fistula and for adequate exploration of the pulmonary, pleural, diaphragmatic and hepatic lesions. Drainage through this approach and repeated packing, if necessary, of a bleeding hepatic abscess cavity is readily accomplished.

CONGENITAL ATRESIA AND TRACHEOESOPHAGEAL FISTULA

Four Consecutive Cases of Successful Primary Esophageal Anastomosis

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THE CASES discussed in this paper are presented with two purposes in mind (1) to direct attention again to a congenital anomaly which if untreated is incompatible with life, but which now can frequently be satisfactorily corrected by surgical procedures, and (2) to discuss certain steps in the care of these patients which have not been emphasized in previous reports by others.

The most common congenital anomaly of the esophagus is complete atresia, the upper segment ends in a blind pouch and the lower segment communicates with the trachea near the bifurcation. It is now generally agreed that in these cases the esophagus should be explored, the fistula ligated and if possible an end-to-end anastomosis of the esophagus, as recommended by Haight,¹ performed. If the anomaly is such that an anastomosis is not feasible, the oral segment is exteriorized, the fistula ligated at the trachea and a gastrostomy performed. The two external fistulas are later joined by some type of antethoracic channel (Ladd,² Longmire and Ravitch³)

From March 1945 to November 1946, 5 infants with congenital atresia of the esophagus and tracheoesophageal fistula were operated on. In all instances the fistula was ligated and an end to end anastomosis of the esophagus performed. The first patient died immediately after operation. In the last four consecutive cases the operations have been successful. These children are taking all feedings by mouth and are gaining weight satisfactorily. One infant in whom a successful repair was performed was born prematurely at seven months' gestation, and weighed only 1,400 Gm (31 pounds) at the time of operation. In general, our treatment in these cases has followed that recommended by Haight.¹

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1 Haight, C., and Towsley, H. A. *Surg., Gynec. & Obst.* **76** 672, 1943
Haight, C. *Ann Surg* **120** 623, 1944

2 Ladd, W. E. *New England J. Med.* **230** 625, 1944

3 Longmire, W. P., and Ravitch, M. M. *Ann Surg* **123** 819, 1946

DIAGNOSIS AND PREOPERATIVE TREATMENT

Diagnosis and preoperative treatment have been amply discussed by Haight,¹ Humphreys,⁴ Daniel,⁵ Ladd,² Lam⁶ and others. There are a few pertinent points, however, which should be emphasized.

Passing a small catheter down the esophagus as a diagnostic measure may give misleading information unless the procedure is carried out under a fluoroscope, as the catheter may double back in the dilated upper esophageal pouch so readily as to give the impression that it is



Fig 1.—Roentgenogram of chest and abdomen of J. B. The oral segment of the esophagus filled with iodized poppyseed oil ends at the level of the second dorsal vertebra. Fluoroscopy demonstrated that segment descends to the level of the fourth dorsal vertebra. Air in the stomach and intestine indicates communication between the distal esophageal segment and trachea.

passing through the esophagus into the stomach. This mishap occurred in 1 case and delayed the proper diagnosis for several hours.

⁴ Humphreys, G. H. *Surgery* 15:801, 1944.

⁵ Daniel, R. A. *Ann. Surg.* 120:764, 1944.

⁶ Lam, C. R. *Surgery* 20:174, 1946.

Before operation the length of the upper esophageal pouch can best be determined by observing the segment filled with iodized poppyseed oil 40 per cent or diodrast under the fluoroscope. The segment undergoes frequent contractions as the infant cries or swallows, and if only a single roentgenogram is taken it may happen to be made during a period of contraction. Thus the picture will show such a short oral segment that the advisability of attempting a primary esophageal anastomosis might be questioned, whereas a much greater length would be demonstrated by fluoroscopy (fig 1). Immediately after the roentgen examination the opaque material is removed from the upper esophageal segment to prevent its aspiration. If too great a quantity of opaque solution is placed in the oral segment it may be aspirated into the lower

TABLE 1.—*Condition of Patients Before Operation*

Case	Age	Term or Premature	Weight, Gm	Level Upper Segment	Air in Stomach	Pneu- monia	Hydra- tion	State of Anomaly (Vogt)	Type III B	Other Anomalies
C M	6 days	Premature 7 months	1,600	4th dorsal vertebra	Yes	No	Good	III B		Cleft palate, atresia ex- ternal audi- tory canal, left
T P	6 days	Term	2,420	5th dorsal vertebra	Yes	No	Good	III B		None
M A	6 days	Term	2,610	4th dorsal vertebra	Yes	No	Fair	III B		Meningocele
J B	3 days	Term	2,400	4th dorsal vertebra	Yes	Rales at both lung bases	Good	III B		None
P W	8 days	Premature	1,400	3rd dorsal vertebra	Yes	No	Good	III B		Atresia of anus, recto- vaginal fis- tula

portion of the trachea. A subsequent roentgenogram of the chest may show the material below the level of the blind pouch, thus suggesting that the patient has a stricture of the esophagus rather than a true atresia.

All of the infants in the series discussed in this paper were in relatively good general condition when first seen, and after a brief interval to allow adequate hydration and blood transfusion, operation was performed. Constant suction was maintained by means of a catheter in the nasopharynx, and penicillin was given until the time of operation. The condition of these patients before operation is summarized in table 1.

OPERATIVE TECHNIC

In all cases ether-cyclopropane anesthesia was used, and no ill effects from the anesthesia have occurred. Quiet respirations were considered essential for the

delicate anastomosis. It is very important that a small catheter be placed through the nose or mouth into the upper segment and constant suction maintained throughout the operation. In 2 cases this was not done, and the omission probably caused the death of the first infant and almost caused the death of the second. In both instances the operation progressed satisfactorily until the mediastinum was opened and mobilization of the upper esophageal segment begun. At this point evidence of severe respiratory obstruction developed. In the first patient this was considered a result of a small opening which had been made in the pleura although there had been no change in the respirations for several minutes after this opening was noted. The operation was continued under positive pressure anesthesia. The anesthetist reported that an unusually high pressure was required to obtain adequate respiratory exchange. At the end of the operation an unsuccessful attempt was made to aspirate the trachea, and the child died a short time later with signs of respiratory obstruction. In the next case similar signs appeared at the same stage in the operative procedure, and as the pleura was intact it was felt certain that the respiratory embarrassment was due to an obstruction in the trachea. Rapid intratracheal aspiration of a small plug of mucus by the anesthetist, Dr. Merle Harmel, completely relieved the obstructive sign. Undoubtedly manipulation caused contraction of the upper esophageal segment and emptying of accumulated mucus, which was then drawn into the trachea. Since that time a suction catheter has always been left in the upper segment throughout the operation, and there has been no further interference with pulmonary ventilation during the procedure. It is possible that some of the respiratory difficulties which have been attributed to the presence of an accidental pneumothorax during this operation may best be explained on this basis.

A right posterior extrapleural approach was used. Segments of the third, fourth and fifth ribs were resected and the pleura was reflected. In the smaller infants it was easy to pass posterior to the mediastinum into the opposite side of the thorax if the vertebral column was not carefully watched for. The upper esophageal segment was localized by palpating the catheter, and the prevertebral fascia was opened in this region. The lower segment was usually found distal to the end of the upper blind pouch by identifying the trachea and following it caudally. In the last 2 cases it has not been necessary to divide the azygos vein, and as division of the vein entails considerable risk of perforating the pleura and is about the only step from which serious hemorrhage may arise in the right-sided approach, it is felt that the omission of this step is desirable if possible. Unless the lower segment enters a bronchus or ends in the lower part of the mediastinum division of the azygos vein probably is unnecessary. The esophagus is freed sufficiently to allow the ends to be rotated during the anastomosis, but extensive mobilization of either end has been avoided whenever possible as this tends to interfere with the circulation and creates a larger dead space in the mediastinum for possible infection, and as the esophagus tends to contract longitudinally when freed from its bed, tension on the suture line may actually be increased by wide mobilization. In attempting to make the opening at the most dependent point of the upper blind pouch the suction catheter is advanced until the pouch is elongated, and the opening is made where the tip of the catheter can be palpated through its wall.

The "telescopic" anastomosis described by Haight has been performed in each instance. Two rows of interrupted 5-0 "deknatal" silk sutures have been used. The anastomosis has not been performed over a catheter, as it has been found easier to identify the various layers of the esophageal segments if the lumen is visible. A catheter is passed through the completed anastomosis to test its patency but is immediately removed. In 1 case a catheter was passed through the anastomosis into

the stomach and left in place for ten days. This completely obstructed the passage of saliva through the esophagus, and a second catheter placed in the nasopharynx was necessary to prevent the aspiration of mucus. Such postoperative obstruction of the esophagus undoubtedly increases the risk of aspiration pneumonia. Haight has pointed out that the distention of the small lower segment by such a catheter might well interfere with the blood supply and the healing at the anastomotic area.

A small rubber tissue drain has routinely been placed in the retropleural space. The advantage of maintaining a higher local concentration of penicillin by closing the incision without drainage has recently been discussed by White and Birdsong.⁷

POSTOPERATIVE CARE

The infants are maintained on fluids parenterally administered for forty-eight hours after operation. At this time a Stamm type gastrostomy is routinely performed through a small upper midline incision. At this stage in the postoperative course such a procedure on a well hydrated infant offers little risk. On the other hand, if the operation is delayed until it is made necessary several days later by the development of a stricture or a leak in the anastomosis, the general condition of the infant may be less satisfactory, intravenous therapy quite difficult because of repeated use of all external veins, and the hazards of the procedure greatly increased. Early retrograde dilation through the gastrostomy opening is easily performed if signs of stenosis of the anastomosis appear.

Twelve hours after the gastrostomy has been established small frequent feedings are given through the tube. If the esophageal anastomosis heals satisfactorily a small portion of the gastrostomy feeding is given by mouth on the seventh day after the first operation, and the quantity of the oral feedings is steadily increased until gastrostomy feedings are eliminated. My colleagues and I have maintained the gastrostomy opening for a period of three months to permit retrograde dilations of the esophagus if necessary. Although there is a certain esthetic satisfaction in having such a patient recover without the performance of gastrostomy, there seems little else to recommend the omission of this procedure.

COMPLICATIONS

In 2 of the patients an external fistula developed from the site of the anastomosis after operation. In 1 case the fistula appeared on the tenth day after operation⁸ and in the other patient on the fifth post-

7 White, M. L., Jr., and Birdsong, M. Surgery 20:548, 1946.

8 A catheter had been left in place through the anastomosis after operation, and we feel that it was at least in part responsible for the development of the fistula. The fistula drained much more in this patient than in the other and it healed more slowly, and the stricture which subsequently formed has responded rather slowly to dilations.

operative day. Of the sixteen successful direct anastomoses which have been reported to date, a temporary external fistula has developed in four. Two other patients reported by Haight were known to have a localized leak from the anastomosis which did not drain externally. In both of our cases external drainage ceased spontaneously within eleven days. During the presence of the fistulas continuous suction was maintained in the upper esophageal segment by means of a catheter, and small frequent feedings were given through the gastrostomy.



Fig 2.—M.A., three and one-half months after operation. Gastrostomy opening is closed. The general condition is excellent.

Every effort was made to prevent the gastric juice or gastric contents from entering the sinus tract. As we feared that the presence of a radiopaque substance in the tract might tend to retard spontaneous healing, no attempt was made to demonstrate the fistula by roentgen examination. The prompt spontaneous closure of the defect suggests that these measures are sound.

In 2 patients a stricture developed at the anastomosis. One of these became evident three weeks after the closure of an external fistula,⁵



Fig 3—J.B. one month after operation. Incision is well healed. Gastrostomy tube is in place, but the child takes all feedings by mouth.



Fig 4—P.W., incision is well healed, the patient taking all feedings by mouth two weeks after operation. The child weighed 3 pounds (1,306.7 Gm) at the time of operation.

the other developed in a patient in whom the anastomosis had healed primarily. At the first sign of stenosis the esophagoscope was used, the nature of the stenosis was determined,⁹ and a string was passed through the esophagus for biweekly retrograde dilations through the gastrostomy. Dilations were continued until a no. 20 French dilator could be passed with ease. The children took all feedings by mouth regularly. The experience of others thus far seems to indicate a better prognosis as regards such strictures than in the case of the usual caustic or traumatic stricture. Several cases have been reported in which an early stricture at the anastomosis has disappeared as the child grew.

TABLE 2.—*Postoperative Course and Results in Infants in Present Series*

Case	Date of Operation	Operation	Gastrostomy	External Fistula	Stricture	Interval Since Operation	Condition
C M	3/1/40	Right extrapleural mediastinal exploration, ligation tracheoesophageal fistula, end to end anastomosis esophagus					Died fifteen minutes after completion of operation
T P	7/27/40	Right extrapleural mediastinal exploration, ligation tracheoesophageal fistula, end to end anastomosis esophagus	Yes 8/12/40	Yes appeared 8/6/40 closed 8/17/40	Yes appeared 8/6/40	6 mos	Retrograde dilations by L M D French no. 22 dilator passed easily once a week, taking all feedings by mouth, gaining weight satisfactorily
M A	8/17/40	Right extrapleural mediastinal exploration, ligation tracheoesophageal fistula, end to end anastomosis esophagus	Yes 8/19/40	Yes appeared 8/22/40, closed 8/26/40	No	5 mos	Taking all feedings by mouth gastrostomy opening closed, esophagus narrowed at site of anastomosis but barium passes readily, meningocele repaired 12/21/40
J B	11/1/40	Right extrapleural mediastinal exploration, ligation tracheoesophageal fistula, end to end anastomosis esophagus	Yes 11/4/40	No	Yes appeared 11/15/40	2½ mos	Retrograde dilations weekly by L M D with French no. 20 dilator takes all feedings by mouth, gaining weight satisfactorily
P W	11/22/40	Right extrapleural mediastinal exploration, ligation tracheoesophageal fistula, end to end anastomosis esophagus	Yes 11/24/40	No	No	2 mos	Excellent takes all feedings by mouth retro vaginal fistula closed and rectum brought to outside through rectal sphincter

older. Certainly a localized stricture of this type should respond better to dilations than the broad extensive scarring encountered in the severe caustic stricture. The great increase in the size of the entire esophagus as the child grows should also help to increase the lumen of the stenotic area.

COMMENT

The most important step in the management of these cases is the early recognition of the anomaly by the attending physician before the

⁹ Esophagoscopy demonstrated the anastomosis to be well healed but narrowed in one patient. In the other patient the lumen at the anastomosis was narrowed and partially obstructed by granulation tissue. This patient has responded more slowly to dilations.

infant's life is seriously threatened by aspiration pneumonia or dehydration and starvation. The success or failure of the operative procedure depends in large part on the general condition of the patient at the time of operation. Prior to Haight's report of the first successful case in 1943 these anomalies were generally considered incurable and their recognition of relatively little importance. The 4 consecutive successful cases in the present series, it is hoped, will emphasize the belief that this view is no longer tenable.

It has previously been suggested that infants having this anomaly and weighing less than 4 pounds (1.8 Kg.) at birth probably should not be operated on. Two of the patients in this series were under this minimal birth weight, and in both it was technically possible to perform a satisfactory anastomosis. The first child died immediately after operation from a condition which I now believe can be prevented. In the second child the anastomosis healed by first intention and the repair has been one of the most satisfactory in this series. Operation should not be deferred solely because of the infant's weight.

SUMMARY

Four consecutive patients with tracheoesophageal fistula and esophageal atresia have survived ligation of the fistula and primary anastomosis of the esophagus. They are now taking all feedings by mouth and are gaining weight satisfactorily. One of these patients weighed only 3.1 pounds at the time of operation. Certain features of the diagnosis, the operative technic and the postoperative care are discussed. The importance of the early recognition of the condition by the attending physician is emphasized.

The anomaly was originally recognized in patient T. P. by Dr. R. W. Frankmann of Massillon, Ohio, and in patient J. B. by Captain Robert T. Parker of Fort Eustis, Va.

Since the completion of this paper an excellent report by Ladd and Swenson of the cases of atresia of the esophagus and tracheoesophageal fistula at The Children's Hospital, Boston, has appeared. Among the last 14 patients treated by primary anastomosis there has been only one death.¹⁰

10 Ladd, W. E., and Swenson, O. Ann Surg 125: 23, 1947.

OPEN REDUCTION FOR FRACTURES OF THE PELVIC GIRDLE

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OPEN reduction for derangement of the pelvic girdle is rarely mentioned in the literature Noland and Conwell¹ resorted to two open reductions in a series of 185 cases of fracture of the pelvis. They stated that the only reason for surgical intervention is pressure of the fragments on the bladder or the rectum. Their procedure is not described. Leadbetter² found it necessary to operate in 2 cases out of a total of 78 reported. His indication for operation was overriding, irreducible fragments. In regard to operative technic, he simply stated that an incision is made over the superior ramus which is reduced and fixed. The inferior ramus is disregarded. Wilson³ advocated bringing the fractured rami together and fixing them with silver wire. Kreucher⁴ concurred with Noland and Conwell's criteria for operation, but reported no operative case. Steele⁵ has done two open reductions for Malgaigne fracture. He placed a dowel type of bone graft across the symphysis pubis and two weeks later performed arthrodesis of the sacroiliac joint. Tierny⁶ expressed the belief that double vertical fractures of the pelvis require open reduction. He advocated making an incision in the anterior part of the perineum in the genitocrural groove, securing the pubic arch with a piece of Parham band and then fixing the wing of the ilium to the sacrum with a 5 cm wood screw. He added that his patients walk in one month, but he did not report any cases.

From the Department of Surgery, Baylor University College of Medicine, and Hermann Hospital

1 Noland, L, and Conwell, H E Acute Fractures of the Pelvis, J A M A 94 174 (Jan 18) 1930, Fractures of the Pelvis, Surg., Gynec. & Obst 56 522 (Feb) 1933

2 Leadbetter, G W Fractures of the Pelvis, South M J 25 742 (July) 1932

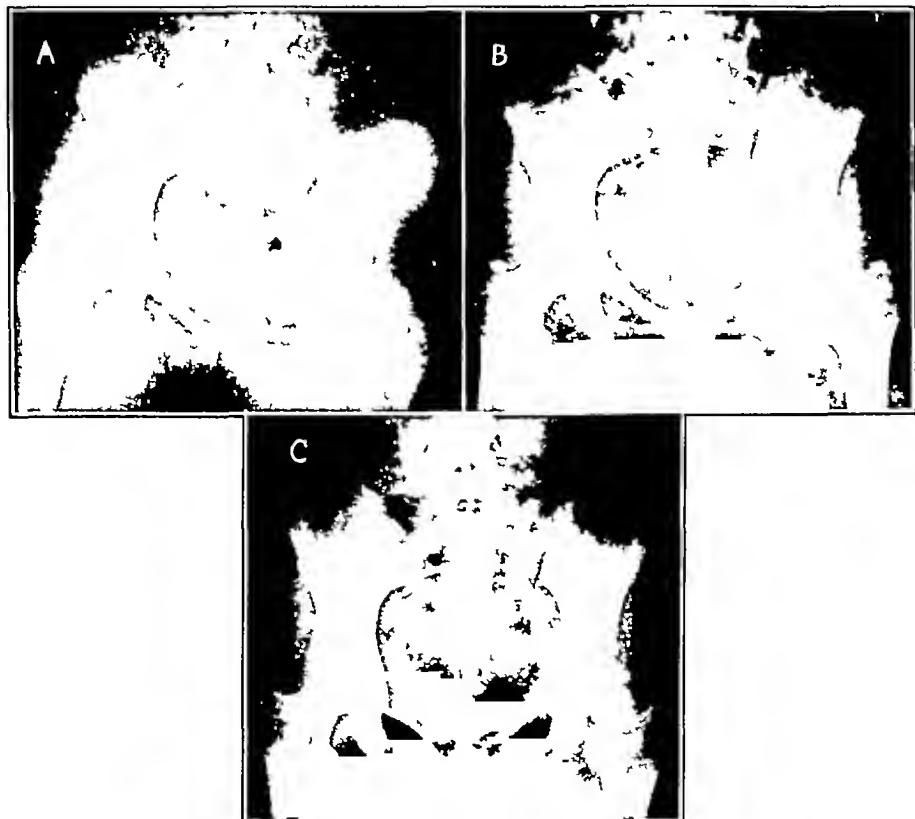
3 Wilson, G E Fractures of the Pelvis, St Michael's Hosp M Bull 3 56 (Dec) 1927

4 Kreucher, P H Fractures of the Pelvis, Indust Med 5 185 (April) 1936

5 Steele, P B, in Bancroft, F W, and Murray C R Surgical Treatment of the Motor Skeletal System, Philadelphia, J B Lippincott Company 1945 p 875

6 Tierny, A Osteosynthesis of Double Cervical Fracture of the Pelvis, Mem d Acad de chir 65 831 (June) 1939

The amount of displacement of fractures of the pelvic girdle is of clinical importance only when it involves wide spreading of the symphysis pubis, marked elevation of one side of the pelvis or impending damage to a viscus or major blood vessels. In such cases, when accurate anatomic reduction is imperative and manipulation is dangerous or impossible, open reduction offers the only solution to the problem. Therefore we wish to present this illustrative case with a technic for open reduction that we have not found previously described in the literature.



A, anteroposterior view of the pelvis taken at the time of the patient's admission to the hospital. The medial fragment is rotated almost 90 degrees on its axis. Note the separation of the sacroiliac joint. B, the postoperative roentgenogram, showing excellent alinement of the pubic fractures. There is little or no change in the sacroiliac joint. C, this view, taken seven weeks after open reduction, reveals bony union of the pubic fracture but still little change in the sacroiliac joint. There were no symptoms referable to the sacroiliac region or symphysis pubis at this time.

REPORT OF A CASE

D P., a white girl aged 16, was admitted to Hermann Hospital on May 29, 1946 after an automobile accident. She complained of severe pain in the pelvis with radiation of the pain to both legs. There was moderate swelling of the right leg and tenderness over the right pubis. The right femoral pulse could be palpated

but was weaker than that on the left. The blood pressure was 130 systolic and 80 diastolic, the temperature was 99.6 F and the respiration rate was 18.

Urinalysis showed 5 to 10 red blood cells per low power field. Other laboratory data and physical observations did not show any abnormality.

A cystogram was done shortly after admission and no trauma to the wall of the bladder could be demonstrated, nor was any extravasation of the opaque mediums noted.

Roentgenograms of the right femur revealed no fracture, those of the pelvis revealed a Malgaigne type of fracture on the right side (fig 1).

In view of the swelling of the right leg and diminution of the femoral pulse, open reduction was decided on and performed June 4.

A satisfactory reduction of the pubis was obtained, but there was little change in the sacroiliac separation (fig 2).

Postoperatively a Roger Anderson well leg traction apparatus was applied with the hope of improving the position of the sacroiliac relationship. This was worn for six weeks. The pelvis was left unsupported throughout the postoperative convalescence. Eight weeks after operation the patient was walking without assistance. On July 26 the roentgenologist reported firm bony union of the pubic fractures (fig 3). The patient was last seen on September 15, at which time she was carrying out her normal activities without any complaints.

DESCRIPTION OF OPERATION

The operation was performed as follows. A Pfannenstiel type of incision was made through the skin and subcutaneous fascia. The anterior aponeurosis of the rectus muscles was incised transversely and the interval between the rectus muscles freed by blunt and sharp dissection, thus mobilizing the rectus muscles. The sheath of the rectus was then incised transversely after retracting the rectus muscles laterally. The peritoneum was avoided by inflating the bladder and later collapsing it. The fascia and periosteum over the superior ramus were incised transversely and the site of the fracture exposed by subperiosteal dissection. Since the fracture was now fully mobilized it could easily be reduced, and if it was not comminuted no internal fixation was required. The wound was closed in layers, and the fracture could then be treated as a nondisplaced pelvic fracture.

CONCLUSIONS

We believe that this approach has the following advantages. The wound is less liable to infection in that it is more removed from the perineal region than other incisions. By section of the rectus and its sheath the medial fragment is mobilized and reduction is thus greatly facilitated. The pelvic viscera and vessels may be observed and the danger of damaging these structures during manipulation of the fragments is eliminated. Large hematomas which are frequently present, may be evacuated.

It is also felt that if the surfaces of the sacroiliac joint are brought into reasonably close approximation arthrodesis or other fixation is not necessary. This is also true of the symphysis pubis.

SUMMARY

The literature bearing on open reduction for fracture of the pelvic girdle has been briefly reviewed. The indications for open reduction are cited. An illustrative case is presented. A surgical approach for reduction of the fractures, which we have not found previously suggested, has been described.

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EFFECTS OF SUPRADIAPHRAGMATIC SECTION OF THE VAGUS NERVES IN MAN

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VARIOUS studies have been performed on a group of patients undergoing section of the vagus nerves for peptic ulceration¹ on the Third (New York University) Surgical Division, Bellevue Hospital. Moreover, Dr Frank B Berry, Director of the First (College of Physicians and Surgeons) Surgical Division, has permitted us to make observations on a small group of patients undergoing similar procedures on that service.

We have outlined a plan of investigation devoting attention not only to alterations in gastric physiology but to other visceral functions proved or suggested by animal experimentation to be mediated through the vagus nerves. All of these studies require further pursuit and analysis. However, certain findings which seem to us to be of some significance are presented at this time. They are as follows: (1) the effect of alcohol intragastrically and intravenously on secretion of gastric acid, and its relation to the effect of histamine, (2) the result of nitrogen balance studies on patients subjected to section of the vagus nerves, (3) the results of electroencephalographic tracings before and after operation, and (4) that which appears to us to be the effect most unpleasant to the patient—namely, diminished gastric motility.

Read at the Clinical Congress of the American College of Surgeons, Cleveland
Dec 19, 1946

1 (a) Dragstedt, L R., and Owens, F M Supra-Diaphragmatic Section of the Vagus Nerve in Treatment of Duodenal Ulcer, Proc. Soc. Exper Biol & Med 53: 152-154, 1943 (b) Dragstedt, L R., and Schifer P W Removal of the Vagus Innervation of the Stomach in Gastroduodenal Ulcer, Surgery 17: 742-749, 1945 (c) Dragstedt L R Vagotomy for Gastroduodenal Ulcer, Ann Surg 122: 973-989, 1945

All patients on whom physiologic observations are herein reported underwent transthoracic supradiaphragmatic section of the vagus nerves for duodenal or gastrojejunal ulcer. Our technic is similar to that described by Grimson.² Lack of secretion of gastric acid in response to hypoglycemia induced by 15 units of insulin administered intravenously was the criterion used for evaluation of complete vagal section.³ In the performance of the gastric tests, the fasting stomach was aspirated as thoroughly as possible by stomach tube. The secretion of gastric acid was determined in the usual way by Topfer's reagent and phenolphthalein on fractional specimens. The alcohol test meal consisted of

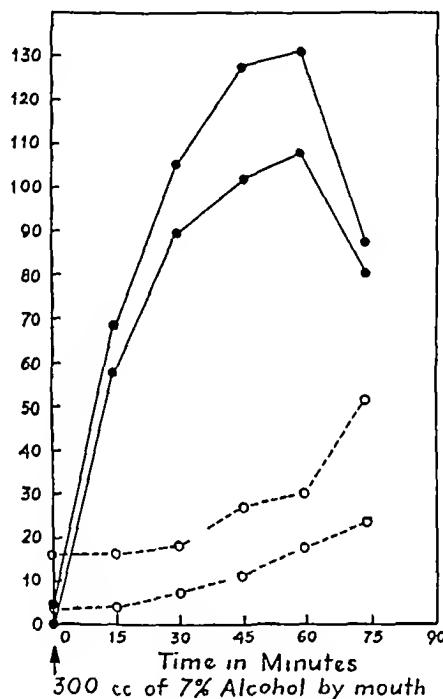


Chart 1.—Gastric acid values after alcohol test meal. The solid lines indicate values before operation and the dotted lines values after operation. The patient was T H.

300 cc of 7 per cent ethyl alcohol introduced into the stomach. For the intravenous method, 0.25 cc of absolute ethyl alcohol per kilogram of body weight was made up into a 25 per cent solution by dilution with

2 Grimson, K. S., Taylor, H. M., Trent, J. C., Wilson, D. A., and Hill, H. C. The Effect of Transthoracic Vagotomy upon the Functions of the Stomach and upon the Early Clinical Course of Patients with Peptic Ulcer, *South M. J.* 39:460-472, 1946.

3 Jemerin, E. E., Hollander, F., and Weinstein, V. A. A Comparison of Insulin and Food as Stimuli for the Differentiation of Vagal and Non-Vagal Gastric Pouches, *Gastroenterology* 1:500-512, 1943.

sterile distilled water and introduced into an antecubital vein.* Studies were performed before and after operation and a comparison of results was made.

In the 7 cases in which the alcohol gastric test meal was employed, all demonstrated a definite decrease in the amount of free and total acid secreted after supradiaphragmatic section of the vagus nerves (chart 1).

Observations were made on 2 patients to whom the alcohol was administered by the intravenous route. A similar definite decrease in the amount of free and total acid was found following section of the vagus nerves (chart 2).

To 1 patient the usual alcohol test meal was given, followed in two hours by the administration of 1 mg of 1 to 1,000 histamine dihydro-

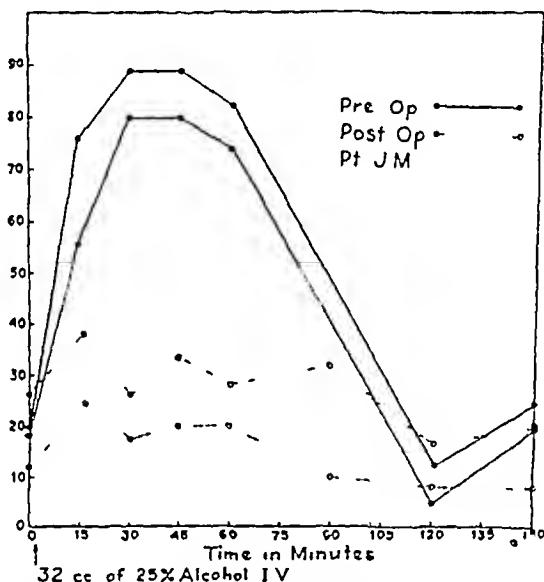


Chart 2.—Gastric acid values after intravenous administration of alcohol. The solid lines indicate values before operation and the dotted line values after operation. The patient was J M.

chloride subcutaneously. After transthoracic section of the vagus nerves there was found to be a decrease in the amount of free and total acid in response to alcohol, but no change with histamine (chart 3). The response to histamine is in accord with the observations of Thornton, Storer and Dragstedt,⁵ who have reported that in 19 patients in whom

4 Newman, H. W., and Mehrtens, H. G. Effect of Intravenous Injection of Ethyl Alcohol on Gastric Secretion in Man, Proc. Soc. Exper. Biol. & Med. 30: 145-148, 1932.

5 Thornton, T. F., Jr., Storer, E. H., and Dragstedt, L. R. Supradiaphragmatic Section of the Vagus Nerves. Effect on Gastric Secretion and Motility in Patients with Peptic Ulcer, J. A. M. A. 130: 764-771 (March 23) 1946.

histamine produced an abundant secretion of acid gastric juice before operation there was no diminution either in volume or in free acidity after section of the vagus nerves

One theory that has been proposed as to the manner in which alcohol increases secretion of gastric acid is that it acts on the gastric glands by liberating histamine.⁶ Since section of the vagus nerve appears to alter the gastric acid response to alcohol and does not alter the response to histamine, the evidence suggests a dissociation of the means by which these drugs effect secretion of gastric acid.

Nitrogen balance studies were done on 4 patients under the direction of Dr Co Tui. The nitrogen balance was positive by the fourth or fifth day, which is the usual finding in patients undergoing operations of comparable type and magnitude. The figures for fecal nitrogen were

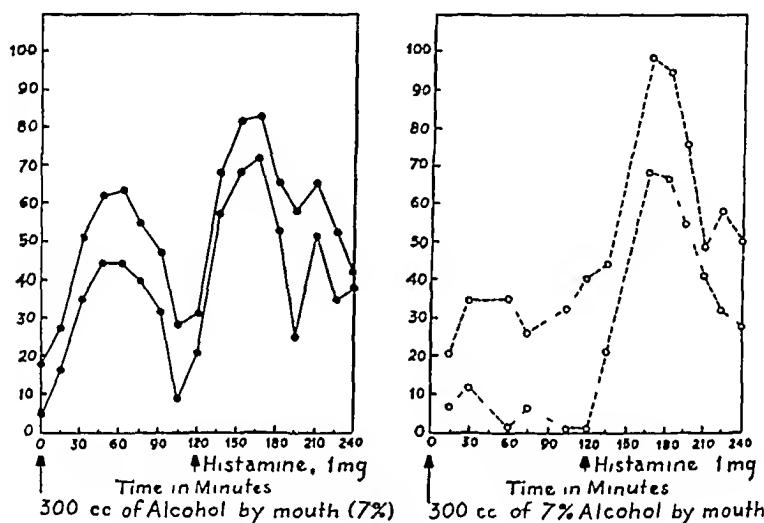


Chart 3.—Gastric acid values after alcohol test meal and injection of histamine. The chart at left indicates values before operation and the chart at right values after operation. The patient was I G.

within or below normal limits. These facts suggest that there has been no impairment of utilization and absorption of protein.

Electroencephalographic studies were done by Dr Margaret Kennard. Six patients had electroencephalographic tracings before and at intervals varying from two days to two months after supradiaphragmatic section of the vagus nerves. All showed a pattern varying from the normal,

6 Dragstedt, C A, Gray, J S, Lawton, A H, and Ramirez de Arellano, M. Does Alcohol Stimulate Gastric Secretion by Liberating Histamine? Proc Soc Exper Biol & Med. 43:26-28, 1940. Ivy, A C. The Mechanisms of Gastric Secretion (E. Starr Judd Lecture), Surgery 10:861-878, 1941. Babkin, B P. Secretory Mechanism of the Digestive Glands, New York Paul B Hoeber, Inc., 1944.

demonstrating either a high percentage of alpha activity or a pattern in which low voltage fast activity was dominant. Neither group showed any significant change in electroencephalographic pattern following section of the vagus nerves. This would indicate that the abnormal electroencephalographic patterns found in a high percentage of patients with peptic ulcer⁷ were not caused by afferent stimuli traversing the vagus nerves.

Of great concern to patients submitted to supradiaphragmatic section of the vagus nerves for duodenal ulcer has been the disturbance of gastric motility. Previous authors have described the occurrence of diminished gastric motility⁸ and warned of the dangers of simple section of the vagus nerves in the presence of pyloric obstruction⁹. None of our patients on whom supradiaphragmatic section of the vagus nerves was performed had pyloric obstruction. None had gastric retention of a barium meal beyond three hours. However, all had histories of duodenal ulcer of at least eight years' duration. After operation, all have shown evidence of diminished gastric tone manifest by (1) a dilated stomach demonstrated by roentgenographic examination, (2) retention of food in many instances for twenty-four to forty-eight hours as found by gastric aspiration (in some patients the dilation is extraordinary and unless treated by aspiration and suction is alarming), and (3) subjective symptoms of fulness, distention, gaseous eructations and an unpleasant taste in the mouth.

Most patients have been pleased with their improvement, relief of pain and increased appetite for the first two weeks after operation. They then become dissatisfied because of the symptoms which we believe arise from diminished gastric motility in the presence of duodenal scarring. All patients have gained weight, and most weigh more now than at any other time in their lives. Meanwhile, other patients with ulcer have been content with the clinical result brought about by subtotal gastric section or by infradiaphragmatic section of the vagus nerves with accompanying posterior gastroenterostomy. Strikingly encouraging results immediately and on short term follow-up, have followed transthoracic supradiaphragmatic section of the vagus nerves in the presence of stomal gastrojejunal ulcer.

7 Rubin, S., and Bowman, K. M. Electroencephalographic and Personality Correlates in Peptic Ulcer, *Psychosom Med* 4:309-318, 1942. Moses, L. Psychodynamic and Electroencephalographic Factors in Duodenal Ulcer, *ibid* 6:405-409, 1946.

8 Barron, L. E., and Curtis, G. M. Effect of Vagotomy on Gastric Motor Mechanism of Man, *Arch. Surg.* 34:1132-1158 (June) 1937.

9 Dragstedt^{1c}; Grimson and others²; Moore, F. D., Chapman W. P., Schulz, M. D., and Jones, C. M. Transdiaphragmatic Resection of the Vagus Nerves for Peptic Ulcer, *New England J. Med.* 234:241-251, 1946.

Our clinical experience up to this time has led us to the following opinions 1 The effects of diminished gastric motility on the subjective sensations of the patient have not been sufficiently emphasized in the previous literature 2 Simple complete section of the vagus nerves performed from below the diaphragm appears to be a satisfactory method of denervation, and if the ill effects of diminished gastric motility are avoided it might follow that the best treatment would be a combination of subtotal gastric resection or gastrojejunostomy^{2c} with complete division of the vagus nerves performed at the same time

SUMMARY AND CONCLUSIONS

Studies before and after operation on a small group of patients submitted to supradiaphragmatic section of the vagus nerves for duodenal or marginal ulcer have demonstrated certain facts which are considered to be of sufficient interest to warrant presentation in a preliminary report 1 The secretion of gastric acid in response to alcohol administered intravenously or intragastrically appears to be diminished after section of the vagus nerve 2 Section of the vagus nerve does not change the electroencephalographic pattern of patients with peptic ulcer 3 Nitrogen balance studies did not indicate any impairment of utilization and absorption of protein as a result of supradiaphragmatic section of the vagus nerve 4 Diminished gastric motility has been found clinically and roentgenographically Certain unpleasant symptoms have been attributed to the resultant dilated stomach

REVIEW OF UROLOGIC SURGERY

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KIDNEY

Congenital Anomaly—Headings and Palmer¹ report a case of supernumerary kidney with the ureter opening into the vagina in a 24 year old white woman, whose chief complaint was dribbling from the vagina. This makes a total of 44 such cases which have been reported in the literature. In this case successful surgical removal of the small supernumerary kidney with its ureter resulted in eradication of the patient's complaint of dribbling from the vagina.

Carlson² states that most supernumerary kidneys are located below the normal kidney and are generally smaller than the normally placed kidney. The ureters show considerable variation. Usually the ureters of the supernumerary and normal kidneys fuse before entering the bladder. Complete reduplication may be present. Ectopic ureteral orifices have also occurred, commonly with openings into the vagina or prostatic urethra. Openings into vaginal cysts or into a blind sac have also been found. In some instances the ureter of the upper kidney opened into the pelvis of the lower kidney. The ureter may be absent.

¹ Headings, D M and Palmer R E. Supernumerary Kidney with Ureter Opening into Vagina. Am J Surg 71:370-373 (March) 1946

² Carlson H E. Supernumerary Kidney as a Cause of Uretero-Pelvic Obstruction. J Urol 56:179-182 (Aug) 1946

The writer presents a case in which a supernumerary kidney located beneath the ureteropelvic junction had apparently produced obstruction and together with infection resulted in a calculous pyonephrosis which destroyed the normally placed kidney.

Bell³ states that horseshoe kidney is not a contraindication to pregnancy, although a high percentage of women with horseshoe kidney have a complicated pregnancy or have to have labor induced.

The writer presents a case in which a complicated pregnancy was terminated early, however, the horseshoe kidney was corrected surgically and two subsequent pregnancies were uncomplicated.

Neoplasms—White and Braunstein⁴ state that renal vascular tumors, excluding telangiectasis and varix, may be classified as follows: benign capillary hemangioma, plexiform hemangioma, cavernous hemangioma, malignant hemangiosarcoma, hemangioblastoma.

The capillary angioma exists commonly in the form of a small papillomatous lesion projecting into the calices or renal pelvis. The plexiform and cavernous hemangiomas and the hemangiosarcomas may be found in any portion of the kidney, but usually are found directly under the epithelial lining of the calices or pelvis. These tumors may exist as a solitary lesion or may be concomitant with similar lesions elsewhere in the body. They may vary in size from that of a pinhead to several centimeters in diameter. The sex incidence is about equal. In the majority of cases patients are in the fourth and fifth decades of life, but apparently no age is exempt.

The chief diagnostic symptom presents uncontrollable hematuria associated with significant absence of roentgenologic evidence. Pain is present in any degree but is not a constant factor. Occasionally with the larger tumors it may be the first symptom. If the tumor is of long standing and of sufficient size to alter the renal architecture through obstructive phenomena, or is so located as to produce calycectasis or pyelectasis, it may be detected roentgenographically.

Painful hematuria with significant lack of roentgenologic evidence is always suggestive. Intravenous and retrograde urography is absolutely imperative if a diagnosis is to be confirmed. Nephrectomy is the treatment of choice, since all attempts at controlling hematuria by medical or cystoscopic means have proved unsuccessful.

Hill⁵ states that up to the present time 35 authentic cases of Wilms's tumor in the adult have been recorded in the literature. Four patients

3 Bell, R. Horseshoe Kidney in Pregnancy, *J Urol* **56** 159-161 (Aug) 1946

4 White, E. W., and Braunstein, L. E. Cavernous Hemangioma A Renal Vascular Tumor Requiring Nephrectomy, an Unusual Entity, *J Urol* **56** 183-189 (Aug) 1946

5 Hill, R. M. Embryoma of the Kidney in the Adult, *Brit. J Urol* **18**, 53-59 (June) 1946

survived for an appreciable time. A mass in the loin or abdomen, pain and hematuria are the most common symptoms. The writer reports a case in a 35 year old woman who was treated by nephrectomy followed by a course of high voltage roentgen therapy (3,500 r). Five years following operation the patient was in excellent health and there was no evidence of recurrence.

Lasher⁶ reports a case in which a hypernephroma was removed from the retroperitoneal tissues outside the kidney. The possible sources of such a neoplasm are discussed. Attention is directed toward the fact that, in general, adrenal rests are found in association with structures derived from the mesonephros or in their paths of descent. Tumors of either hypernephroid or androgenic type may arise from these ectopic islands of adrenal cortex.

Hydronephrosis.—In a series of articles on hydronephrosis, Hinman⁷ states that the tubular structure of the kidney has been studied over the years by means of just two methods, reconstruction and teased dissection. Unfortunately, neither method demonstrates satisfactorily the later changes of hydronephrosis and consequently investigators interpret differently the discoveries made by the same method. Many questions may have to remain unanswered unless a newer, more accurate method of demonstrating the changes is discovered.

In the past, descriptions concerning chiefly the changes occurring after complete ureteral obstruction in experimental animals have been confined too closely to tubular changes. Basically hydronephrosis is glomerular, and thus in the pathogenesis of hydronephrosis the vascular changes are no less important than the tubular.

The unit of renal function is not the tubule. It takes a group of glomerulotubules to form such a unit, and this is locked inseparably with blood supply. Conclusions from a study of tubular changes alone are thus incomplete.

In the progression of hydronephrosis, glomeruli remain longest. Because soon different components of the unit cannot be distinguished, the tubular changes are hard to follow microscopically and what has happened to the individual tubules of the surviving glomeruli has long been a matter of conjecture. In man, the variation in the rate of tubular atrophy in different renal portions varies according to the circulatory arrangement. Pressure atrophy is more or less uniform throughout the kidney, but anemic atrophy is not.

⁶ Lasher, E. P., Jr.: Primary Extrarenal Hypernephroma: Discussion of Sites and Origins, and a Report of a Case, *West. J. Surg.* 55:87-93 (Feb.) 1947.

⁷ Hinman, F.: Hydronephrosis. I. The Structural Changes, *Surgery* 17:816-835 (June) 1945, II. The Functional Changes, *ibid* 17:836-845 (July) 1945, III. Hydronephrosis and Hypertension, *ibid* 17:846-849 (Aug.) 1945.

One can only surmise what happens when all portions of a tubule have atrophied. The method of maceration and dissection is inadequate for answering the question of whether the glomeruli retain a duct through which their filtrates can drain directly into the pelvis or whether they are completely isolated. Perhaps both of these processes occur.

The corticomedullary line is drawn on both vascular and tubular distinctions. Throughout progressive hydronephrotic atrophy the vascular and tubular distribution above and below this line persists in some form. As the interlobar and arcuate vessels stretch and their calibers diminish with pelvic distention, only those interlobular arteries which have not been shut off by the compression continue supplying blood to their glomeruli. These arteries, through postglomerular capillary plexuses and arteriolae rectae, continue to nourish the corresponding tubular components. This leads to great differences in the rate of progress of hydronephrotic atrophy throughout the parenchyma of the same kidney. This accounts for the group distribution of survival, permitting isolated repair nodules in experimental hydronephrosis. There is considerable difference later in the size of glomeruli, which indicates the possibility of compensatory hypertrophy of some glomeruli in this condition.

Pressure atrophy and anemic atrophy combine to produce hydronephrotic atrophy. Tubular and circulatory changes in this condition are interrelated.

Hydronephrotic atrophy is distinct and separate from primary or any other kind of atrophy. The condition of hydronephrosis presupposes continued secretion of urine in spite of the obstruction. Since many of the structural changes occurring in hydronephrosis are still not understood it is as difficult to correlate structure and function as it is to reconcile normal and hydronephrotic functions.

Experimental and clinical evidence conclusively demonstrates that there are an inflow and an outflow of the contents of a hydronephrotic kidney. Drainage of urine permitting continuation of excretion explains the mechanism of hydronephrotic atrophy. The mechanism of reabsorption in hydronephrosis has not been definitely established, and thereon the main controversy now hinges. A number of pathways of urinary backflow from the renal pelvis have been proved and others suggested. Until the loops of Henle are destroyed, tubular absorption of glomerular filtrate in excess of normal probably occurs. Since the collecting ducts can be filled for a short distance only, pelvic urine would not reach the loops of Henle directly for reabsorption. Physiologic backflow and reabsorption by way of collecting tubules may occur through retrograde distention with transudation into pericanalicular spaces as edema fluid and absorption by capillaries or lymphatics or both. When a pathologic condition is present it may occur through the rupture of

the distended wall of the tubule with extravasation into the capillaries or lymphatics or through slits or both and excavations of the torn papilla into tissue spaces around the collecting tubules

At the fornix calicis the caliceal or pelvic epithelium joins that covering the papilla and in this transition acquires endothelial properties by which a direct relationship to capillaries, similar to that in glomeruli, is established. Physiologic absorption of total urine may occur at this point without fornical rupture under certain conditions of diuresis or peristalsis, the fluid passing either directly into the veins or after marked extravasation into capillaries or lymphatics. In the pathologic state, multiple fornical ruptures occur which would permit urine to pass either directly into the veins or into the tissue spaces with flow into veins or lymphatics. This mechanism cannot be effective after the third week of obstruction, however, since at that time the fornices have disappeared and the interstitial spaces are being filled progressively with newly formed connective tissue.

At this period, because irregular damage to the glomeruli has occurred, some glomeruli are working with a higher filtration pressure than are others. A sufficient difference in blood pressure in two major groups of glomeruli may cause back filtration of the filtrate of the high pressure glomeruli into the low pressure glomeruli. The flow of urine thus does not cease. The eventual destruction of the glomeruli is paralleled by a diminution of this flow.

Some insight into the mechanics of hydronephrosis is obtained by studying blood flow and secretory pressure. Ureteral ligation or partial obstruction of the renal artery or both lower these factors and together speed up the process of hydronephrotic atrophy. Neither prolonged polyuria, in which both these factors are increased, nor prolonged oliguria has effect on the rate of progress of the atrophy. Increased activity of a kidney with a ligated ureter has no effect on the rate of development of hydronephrosis. Unilateral oliguria *per se* has so far been beyond experimental tests.

Hypertension has two possible connections with hydronephrosis. Sometimes it might be an accelerator, at other times an effect. Experimental and clinical studies show that high blood pressure has no influence on the mechanics of hydronephrosis.

The changes of hydronephrosis could well have an effect on blood pressure. The factors supposedly responsible for hydronephrotic atrophy could act to promote renal hypertension. Renal ischemia however is not the essential factor as was formerly thought. It is not yet known how constriction of a renal artery causes hypertension. All attempts to produce permanent hypertension by the simple ligation of one ureter have been unsuccessful. Clinically hypertension is an unexpected complication in simple hydronephrosis. The renal origin of hypertension if seen, is very uncertain.

Renal hypertension appears to depend on the ratio of ischemic to normal renal tissue. In hydronephrosis both of these factors are affected. The magnitude and course of any resulting hypertension depend on the amount of renal ischemia and on the amount of hydronephrotic atrophy of the normal renal parenchyma, as well as on the compensatory increase in normal renal tissue in the opposite kidney. Just as in renal arterial constriction, so is it possible that in hydronephrosis renal excretory insufficiency may develop without the occurrence of hypertension if the decrease in normal parenchyma is inordinately greater than the amount of ischemic renal tissue. In such an event the process leads primarily to destruction of normal renal tissue and this may become great enough to simulate complete nephrectomy. These considerations give little encouragement for the cure by nephrectomy of hypertension occurring in unilateral hydronephrosis.

The attempt to repair every hydronephrotic kidney not entirely destroyed is not only without a common sense basis but may be actually dangerous. The surgical repair may itself so alter the mediators of blood pressure as to cause hypertension later on. A case is cited in which hypertension with symptoms occurred five years following a successful plastic repair and nephropexy of an uninfected hydronephrotic kidney. The renal function had remained the same over the five year period, and there was no evidence of there having been urinary infection during this time. Cure was effected following nephrectomy.

Hypertension is somewhat more common in the presence of bilateral hydronephrosis. The age of the patient may be a factor in the incidence of hypertension in both unilateral and bilateral hydronephrosis. Compensatory hypertrophy is much less marked in older persons and is almost absent in the bilateral condition. Again, it is possible that the kidneys may be only one of many factors causing essential hypertension.

Cases of hydronephrosis studied over a four year period at the University of California Hospital are reviewed. Nephrectomy offered little benefit as regards hypertension in this series.

Owing to the principle of compensatory hypertrophy, a hydronephrotic kidney, as well as its mate, is overstimulated. This is the reason that some units, during certain stages of hydronephrotic atrophy, show hypertrophy or at least are kept more active and resistant. It is also the reason for the rarity of hypertension with hydronephrosis. This overstimulation due to hydronephrosis will disappear, however, when the mate has fully compensated by hypertrophy to carry the overload.

Miscellaneous.—Abeshouse and Tankin⁸ state that administration of any of the common sulfonamide drugs, such as sulfanilamide, sulfa-

⁸ Abeshouse, B. S., and Tankin, L. H.: Renal Complications of Sulfonamide Therapy, *J. Urol.* **56**, 658-687 (Dec.) 1946.

pyridine, sulfathiazole, sulfadiazine or sulfamerazine, may be complicated by toxic and irritative lesions of the upper part of the urinary tract

The toxic manifestations of such renal complications are (*a*) crystalluria, (*b*) hematuria, (*c*) oliguria or anuria, (*d*) azotemia (*e*) renal or abdominal pain (*f*) tenderness over the kidneys and ureters, (*g*) enlargement of the kidney and (*h*) albuminuria

The pathologic changes produced in the kidneys of experimental animals and in human beings after prolonged administration or overdosage of sulfonamide drugs are of two types, namely (*a*) mechanical changes caused by the deposition of crystals or concretions in the renal tubules, pelvis or ureters and (*b*) chemical changes, such as acute toxic and degenerative nephritis (calcifying nephrosis). The renal complications are the result of the poor solubility of these drugs and their acetyl derivatives. Experimental and clinical studies show that the incidence of these complications is directly related to the solubility of the drug. Renal complications rarely are observed following administration of sulfanilamide, a relatively soluble drug, but frequently are noted following administration of sulfapyridine, sulfathiazole, sulfadiazine and sulfamerazine, which are relatively insoluble drugs.

The chief factors influencing precipitation of the crystals and formation of sulfonamide concretions are (*a*) concentration of the drug in the urine, (*b*) degree of acetylation or conjugation of the drug, (*c*) the presence of an obstructive or inflammatory lesion in the upper part of the urinary tract, (*d*) p_{H} of the urine and (*e*) temperature of the urine.

Crystalluria per se is not an indication of serious renal damage and can be remedied by temporarily withdrawing the drug or decreasing the dosage, forcing fluids and alkalinizing the urine adequately.

Every patient receiving sulfonamide drugs should be under close and constant surveillance for any toxic renal complication, such as hematuria, oliguria or anuria, azotemia or renal or abdominal pain. The occurrence of any one or more of these symptoms demands immediate withdrawal of the drug and the prompt institution of corrective measures.

The occurrence of these complications can be prevented or their incidence can be reduced by adopting the following precautions: (*a*) determining previous sulfonamide medication, drug sensitivity or idiosyncrasy, (*b*) determining renal function before and during drug therapy, (*c*) careful evaluation of state of hydration (water balance), (*d*) administration of drug in accurate dosage to avoid overdosage and (*e*) adequate alkalinization to sustain a p_{H} of the urine of 7.6.

In cases of anuria complicating sulfonamide therapy it may be necessary to employ cystoscopy and ureteral catheterization to distinguish between the mechanical type (obstruction of ureters or pelvis)

by crystals or concretions) and the chemical type (acute toxic and degenerative nephritis)

When the usual corrective measures—increased intake of fluid, alkalinization, ureteral catheterization—fail to improve or restore renal function, it may be necessary to resort to operative methods to prevent uremia

Decapsulation alone or in combination with pyelostomy or nephrostomy or retrograde ureteral catheterization has proved to be lifesaving in otherwise hopeless instances

In 1 case of anuria following sulfadiazine therapy in which the condition failed to respond to the usual conservative measures (including ureteral catheterization) and to decapsulation with nephrostomy, at necropsy evidence of thrombosis of both renal arteries was observed. This complication has not been previously described or reported.

Munger⁹ makes a plea for a more conservative attitude in renal surgery. He states that too many nephrectomies are performed. The surgical correction of hydronephrosis is, for the most part, a perfectly logical and feasible operation. Hydronephrosis is commonly a bilateral disease. Protective splinting with adequate and prolonged intrapelvic drainage is an absolutely necessary procedure in plastic correction of the renal pelvis. About 70 per cent of diseases requiring surgical intervention and of congenital malformation of the kidney are amenable to partial nephrectomy. Total nephrectomy in hydronephrosis should be instituted only when it can be demonstrated that the drainage system is completely destroyed beyond recovery and in renal disease wherein it can be shown that the kidney is utterly worthless.

Ratliff, Nesbit, Plumb and Bohne¹⁰ report the results of urologic studies of 2,055 hypertensive patients. One hundred and eighty-three lesions were found. Hypertension may coexist with any of the common renal lesions, but there is no consistent relationship between hypertension and any particular gross renal lesion. Congenital absence of a kidney, reduplication of pelvis and bilateral lesions occurred in 70 of the cases. Patients in the remaining 113 cases had unilateral lesions. Nine per cent of all the patients studied had renal abnormalities, while less than 5 per cent were candidates for nephrectomy and fewer came to operation.

During the eleven year period (1934 to 1945) in the records of the University of Michigan Hospital 49 cases of severe hypertension treated by nephrectomy were found. In all but 7 of these the systolic

9 Munger, A. D. A Plea for a More Conservative Attitude in Renal Surgery, *J. A. M. A.* **132**: 675-679 (Nov.) 1946.

10 Ratliff, R. K., Nesbit, R. M., Plumb, R. T., and Bohne, W. Nephrectomy for Hypertension with Unilateral Renal Disease. Report of Forty-Nine Cases, *J. A. M. A.* **133**: 296-299 (Feb 1) 1947.

pressure was well over 200 or the diastolic over 100. The follow-up period has been longer than twelve months in all but 8 of these cases. Seventeen patients (34.6 per cent) were considered to have had good results, and 6 (12.4 per cent) were improved, results in 26 cases (53.0 per cent) were failures. In cases in which the results were good the patient was free from hypertensive symptoms and had a normal blood pressure at the time of the last follow-up report. In other words the patient was considered cured according to clinical evidence at the date of check-up examination. Results were regarded as a failure when a patient was not improved by nephrectomy or subsequently died as the result of hypertension.

The authors concluded that when unilateral renal disease is demonstrated by roentgenologic examination it can be treated by nephrectomy, with an expectation of improvement or cure of the associated hypertension in about half of the cases. In their series of cases the greatest incidence of favorable results occurred in the cases of chronic pyelonephritis in adults, hydronephrosis and calculous pyonephrosis. In the group of cases of "infantile chronic pyelonephritis," the incidence of cure was definitely less than that in adults.

The higher percentage of cures falls in that group of patients who have gross urologic symptoms. Fewer good results followed nephrectomy in the group of hypertensive patients who had no urinary symptoms.

Wagner¹¹ presents a modified technic of abdominal arteriography, featuring use of a hand syringe for injection instead of the pressure apparatus. Advantages of the hand syringe method are its simplicity and greater protection against extravasation by allowing detection of change in resistance during injection.

Visualization of the renal artery and its branches is best when the needle is introduced one vertebral level below the classic site.

The difficulties and potential dangers of the procedure can be minimized by a competent team.

One normal and two abnormal arteriograms are presented and interpreted.

Kleiman¹² reports a case of anuria due to sulfathiazole with recovery following renal decapsulation.

Difficulty was encountered with the family in regard to operation, finally permission was granted for unilateral decapsulation, which was done five days after complications developed.

The routine incision in the left loin was made. The perinephric tissues were very edematous and oozed serous material freely. The renal mass with its surrounding perinephric fat resembled a supersaturated sponge. The kidney was enlarged to about one to three fourths times its normal size. It was very turgid. The capsule was under undue strain. When it was nicked, the kidney practically decapsulated itself. Decapsulation was carried down to the renal pedicle and was complete.

On the evening following operation, the patient voided 580 cc. On the second postoperative day, the twenty-four hour output was 1,005 cc. Blood urea on the fifth day was 48 mg, whereas it had been 90 mg before operation. Intravenous pyelograms showed excellent concentration and elimination of contrast medium in five minutes from the left kidney. The right kidney failed to concentrate dye in thirty minutes sixteen days postoperatively. When cystoscopy was performed on the twenty-third postoperative day, indigo carmine was injected and appeared in excellent concentration in five minutes from the left kidney. It failed to appear in one hour from the right kidney.

This case is a typical one of sensitivity to sulfathiazole. A complete genitourinary examination failed to reveal any evidence of sulfathiazole crystals, either in the urine itself or in the upper part of the genitourinary tract. The edematous, cyanotic appearance of the kidney would lead one to suspect that a markedly toxic reaction had occurred within the renal parenchyma.

URETERS

Traumatic Injuries—Herman, Greene and Hayllar¹⁸ have reviewed the literature of the past ten years on the subject of ureteral injury. The fact that fifty-eight papers were found led them to believe that the subject has been well covered and that ureteral injury is a common occurrence.

Ureteral injuries may be classified under three general headings, on the basis of the causative factor (1) external violence, (2) spontaneous rupture and (3) instrumental injuries and surgical trauma.

Ureteral injury from external violence is unusual in civilian practice, but serious injuries may result from pelvic fractures. Even in military surgery comparatively few instances of ureteral injury have been reported.

Spontaneous rupture of the normal ureter is extremely rare. Spontaneous rupture of the diseased ureter, usually at the site of an impacted calculus, is not unusual. Spontaneous rupture of the abdominal segment of the ureter occurred at the site of previous ureterolithotomy when a stone became impacted below this point. The patient was a man aged 60 years. A urinary fistula persisted after incision and

¹³ Herman, L., Greene, L. B., and Hayllar, B. L. Ureteral Injuries, J. Urol. 56: 688-696 (Dec.) 1946.

drainage of the abscess, until a practically functionless and badly infected kidney was removed

Instrumental perforation or rupture of the normal ureter is most unusual, since this structure is highly resistant to perforation by the ureteral catheter. Mild contusions and lacerations are common enough, and the sequelae are well known to every practicing urologist. While stricture may conceivably result from such trauma, the probabilities are that little permanent damage results.

Periureteral abscesses often occur spontaneously at the site of long-impacted stones, but not always as the result of actual perforation with urinary extravasation; in fact, the kidney may be functionless.

Catheter perforation of the ureter, even if followed by periureteral injection of methiodol sodium ("skiodan"), may cause no inconvenience.

Surgical injuries to the ureter occur more frequently in gynecologic operations than in other surgical procedures because of the anatomic relationship of the ureter to the pelvic organs of the female and the difficulty involved in dissection when complications are present. That portion of the ureter which passes through the broad ligament is the most vulnerable.

In the women's clinic at the Pennsylvania Hospital during the period from 1936 to 1945 there were four injuries to the ureter in a total of 7,966 gynecologic operations. No injury to the ureter was recognized during the same period in a series of 15,325 deliveries, which includes 1,568 cesarean sections.

Injury to the ureter may go unrecognized, especially if it is ligation of a ureter. Ureterovaginal fistula may result.

The ureter may be severed during resection of the bladder or diverticulectomy. The injury is usually treated by ligation or reimplantation of the ureter into the bladder. Reimplantation seemed to prolong the life of 1 patient whose opposite kidney was destroyed later by calculous pyonephrosis.

BLADDER

Rupture.—Fiegal and Polzak¹⁴ report 3 cases of spontaneous rupture of the urinary bladder. They state that the most important cause of spontaneous rupture of the bladder is overdistention, on the basis either of prostatic enlargement or urethral stricture. The fuller the bladder, the more likely it is to rupture. Neurogenic dysfunction may also account for some of the cases of overdistention. Alcohol, by dulling the sensorium, delays the urge to void and tends to produce overdistention. Because of this, alcohol is frequently an important etiologic factor in rupture of the bladder whether spontaneous or traumatic.

¹⁴ Fiegal, W. M. and Polzak, I. A.: Spontaneous Rupture of the Urinary Bladder, *J. Urol.* 56: 196-199 (Aug.) 1946.

Long-standing distention with resultant degeneration of the vesical wall and pathologic changes in the wall produced by neoplastic or inflammatory disease also play a role in the production of spontaneous rupture. The rupture is almost invariably intraperitoneal. The patient commonly experiences severe abdominal pain followed by dysuria and urgency. Very frequently he voids a small quantity of grossly bloody urine, after which complete retention is present. The abdomen is usually rigid and tender and frequently a fluid wave and shifting dulness to percussion can be elicited. Hiccups may be present, vomiting and nausea are often prominent symptoms. Leukocytosis with a relative increase in the number of polymorphonuclear cells is noticed almost invariably.

Spontaneous rupture of the urinary bladder is an acute surgical emergency. Laparotomy with aspiration of intraperitoneal fluid, closure of the rent and adequate drainage of the bladder will reduce the mortality and morbidity. Use of penicillin, sulfonamide drugs and care in choice of anesthetic will further improve the prognosis.

Inflammatory Conditions.—Moulder¹⁵ presents a case of thrush of the urinary bladder and discusses the condition. He states that the lesions are soft pearly white slightly elevated patches which resemble deposits of coagulated milk, but they adhere firmly so that the mucosa bleeds when they are removed. Scrapings of the affected parts reveal the filaments and the yeastlike cells.

The case presented is that of a 26 year old white soldier who had experienced attacks of urinary frequency, both nocturnal and diurnal, for eight years. At times frequency and urgency would become intense, and occasionally there was gross hematuria. A constant feeling of discomfort was present in the vesical and perineal regions. Urinalysis showed a cloudy, yellow specimen, pH 5, specific gravity 1.022, trace of albumin, no sugar, 12 to 15 erythrocytes per high power field and 100 leukocytes per high power field. Culture of the urine on Sept. 11, 1944, revealed many colonies of nonhemolytic *Staphylococcus albus* and many colonies of fungus similar to *Monilia albicans*. All subsequent examinations of cultures of urine revealed essentially the same findings except that on October 11 and 20 pure cultures of *Monilia albicans* were isolated under strictly sterile conditions. At cystoscopy a 24 Brown-Buerger cystoscope was passed easily to the bladder. The capacity was 160 cc. The mucosa was involved in a diffuse rather intense inflammatory reaction, the mucosa itself appearing red and slick, but no vessels were prominent except over the trigone. Located just medial to the left ureteral orifice and just above to the left in the bas-fond and up toward the dome of the bladder there were three distinct slightly elevated, white irregular patches measuring about 1 by 2 cm. in diameter. They appeared to be firmly attached to the underlying mucosa. The ureteral orifices appeared normal except for the minor edema of diffuse cystitis. The posterior and anterior parts of the

¹⁵ Moulder, M. K. Thrush of the Urinary Bladder Case Report, J Urol 56 420-426 (Oct.) 1946

urethra appeared normal and were not involved in any ulcerative process. A 6 F catheter was passed easily to each kidney, and clear urine flowed freely from each side. Renal function test with indigo carmine revealed prompt appearance and a 4 plus secretion of the dye. Retrograde pyelograms revealed that the upper part of the urinary tract was normal. On differential count 1 or 2 leukocytes and an occasional erythrocyte from each renal pelvis were found. Neither protozoic nor yeast organisms were found on culture.

The patient was treated with penicillin, irrigations of the bladder with silver nitrate solution and with solution of gentian violet fulguration of the lesions and repeated courses of administration of sulfathiazole during a period of nine months at the end of which time the urine was normal and the vesical mucosa was observed to be normal on cystoscopic examination. Sulfathiazole was apparently the most effective of the various therapeutic measures used.

Crance¹⁰ discusses grain mite infection of the urinary tract and reports 3 cases. Grain mites are sporozoa and are encountered in myriads in foodstuffs which are beginning to ferment. They are particularly abundant in different kinds of cheese such as Parmesan, Cheddar, Gruyere and Dutch cheese. They may be found in the eyes of the cheese but are sometimes present under the crust in which they dig innumerable tunnels. They abound in flour and bread. They may therefore be carried to the digestive system of man with his food and may be found during microscopic examination of the stools.

Crance states that, in looking for the grain mite (*Tyroglyphus longior*) in the urine, the specimen must be centrifuged several minutes at high speed. It may even be necessary to centrifuge several specimens, and it is preferable to use the sediment after a specimen has stood in a conical glass. When looking for the mite, using the low lower lens (and the grain mite is easily seen under low power) one is impressed by the fact that the epithelial cells and the occasional pus cells and other debris occasionally show a motion different from that noticed on examination of a wet smear when everything moves in one direction. Urinary debris and so forth in this instance do not seem to move in the same direction. This should make one suspicious that a grain mite is working in the neighborhood. The slide should then be moved carefully toward the point where this motion seems to be originating. When one is successful in finding it there is no doubt whatsoever as to its identity. The mite will be found moving forward slowly in a side to side lobster-like fashion with his claws busy opening and closing. Careful focusing will reveal the six tails projecting out from the stern. These tails are close together.

Symptoms of the infection consist of frequency of micturition, urgency and nocturia, often of severe degree.

possible. Possibly the eggs reach the bladder through the kidney and ureters, and hatch after implanting themselves on the vesical wall.

In the 3 cases reported treatment consisting of irrigations of the bladder and instillation of 20 per cent solution of mild protein silver ("argyrol") was rapidly successful.

Tahara, Lechner and Hess¹⁷ report 3 cases and discuss the manifestations and treatment of a condition which they feel is a new clinical entity. The condition is characterized by symptoms of marked urinary frequency, stranguria, gross hematuria, a small contracted bladder and dilatation of the ureters from the intramural portion up to and involving the pelvis and calices of both kidneys. They have named the disease "acute interstitial cystitis" and feel that it is an acute inflammation of the muscularis of the vesical wall.

The patients were young males and the condition apparently began with a mild to moderately severe form of urethritis or prostatitis which responded initially to treatment with sulfathiazole or penicillin only to be followed (in three weeks in 2 cases and nine months in the other case) by the more severe vesical symptoms of acute interstitial cystitis. The prognosis is good, treatment with large doses of penicillin was effective. Neoarsphenamine also was used in the 3 cases reported. The writers feel that the diagnosis of this condition can be made from the history and intravenous urograms and that instrumentation should not be used.

Neoplasms—Ockuly and Helwig¹⁸ report a case of endometriosis of the urinary bladder in a 26 year old woman who had experienced symptoms of abdominal pain and frequency of urination for five years. These symptoms were aggravated during menstruation, gradually subsided following it and were minimal immediately prior to the period. Cystoscopic examination showed a mass approximately 4 cm in diameter on the posterior wall of the bladder near the dome and to the left of the midline. The tumor was slightly raised and was covered with short, fine villi, between which an occasional minute, translucent cyst could be seen. The tumor disappeared in several weeks after roentgen therapy. Ockuly and Helwig state that endometriosis of the bladder is varied in symptoms, physical findings and even gross and microscopic appearance depending on the extent of involvement of the wall of the bladder and the stage of the menstrual cycle. Vaginal, cystoscopic and urinary findings may be entirely lacking in the early stages of the disease.

17 Tahara, C., Lechner, C., and Hess, E.: Acute Interstitial Cystitis. A Clinical Entity, J. Urol. 56: 535-543 (Nov.) 1946.

18 Ockuly, E. A., and Helwig, F. C.: Endometriosis of the Urinary Bladder with Report of a Case, J. Urol. 55: 464-469 (May) 1946.

Melicow¹⁹ states that the correct interpretation of a biopsy of the bladder is contingent on the cooperation of urologist, technician and pathologist.

He states that because of the behavior of vesical tumors, the value of a biopsy of the bladder is limited because (a) complete eradication of a benign tumor does not necessarily mean cure because new tumors may develop subsequently, (b) the cell population of a vesical tumor is not always uniform, changes characteristic of malignancy are likely to occur at or near the base and are often inaccessible to the biopsy forceps, and the biopsy, therefore, may or may not be representative of the remainder of the tumor.

The grading of vesical neoplasms is of value for statistical and pathologic studies, and as a shorthand description of a tumor.

Physical factors, size, breadth of the base, the presence of infiltration and extramural involvement of the bladder, as well as the findings at biopsy, should guide treatment and prognosis.

Milner²⁰ discusses treatment of carcinoma of the bladder for the past five years with special reference to the closed method of treatment. For the purpose of simplicity he divided carcinoma of the bladder into two main groups, namely, papillary carcinoma and epidermoid carcinoma. In the first group he has placed all papillary growths, non-infiltrating and infiltrating. In the second he has placed the solid sessile "meaty" types of tumor, most of which, of course are infiltrating. For this paper he has collected 245 cases in which operation was performed on the urologic service at the Albany Hospital from 1940 to 1945. Of these 245 patients 188, or 76.7 per cent, have been accurately followed, 57, or 23.3 per cent could not be traced and for them no record is available.

cent, were treated by the closed method exclusively namely, transurethral resection of the tumor down to and exposing the muscle layer of the bladder wherever the depth of infiltration did not make this impossible. The base of the tumor was then fulgurated. Resection should be carried out so as to remove at least $\frac{1}{8}$ inch (0.32 cm) of what appears to be normal mucosa surrounding the base of the tumor itself. The actual size of the tumor should not always be a contraindication to transurethral resection even though it might be easier for the surgeon to perform cystotomy. Three patients had tumors which weighed more than 100 Gm.

Cases are selected for radium implantation on the basis of the evidence of infiltration seen at preliminary cystoscopy. Milner states the belief that the lessened morbidity accompanying transurethral implantation of radon seeds more than makes up for the greater accuracy obtained by opening the bladder. For high voltage roentgen therapy 4,000 or 5,000 r are given through three portals. High voltage roentgen therapy is employed only in cases of infiltrating tumor in which some extra help is felt necessary. Milner uses it routinely in cases of multiple papillary carcinoma, grade 1, for he feels that it tends to reduce the possibility of recurrence in these cases. In no instance of multiple tumors has the high voltage therapy entirely prevented recurrence, but he feels that the degree of recurrence has been less. Some noninfiltrating carcinomas require neither of these last two procedures.

Partial cystectomy or segmental resection of the part of the bladder involved was performed in 15 cases.

Total cystectomy with transplantation of the ureters to the intestine was carried out in 3 cases. One patient was a poor risk and was operated on largely for relief of intractable pain. The other 2 died as the result of metastasis, 1 two years and 1 twelve months postoperatively. Neither of the tumors in the last 2 cases showed any signs of extension preoperatively or at operation. In 93 cases, or 38.7 per cent, the tumor was an epidermoid carcinoma, in 145 cases, or 60.4 per cent, papillary carcinoma, in 1 case, or 0.4 per cent, malignant melanoma. Ninety, or 37.5 per cent, were grade 3 and 4 tumors, 150, or 63.5 per cent, were grade 1 and 2 tumors, 163, or 67.8 per cent were definitely malignant according to the microscopic diagnosis, 75, or 32.2 per cent, were grade 1 tumors. The operative mortality rate was as follows: total cystectomy, 33.3 per cent (1 patient of 3), partial cystectomy, 6.7 per cent (1 patient of 15), and transurethral resection, 0.4 per cent (1 patient of 225). Of the 189 patients concerning whom definite information is available 71 patients, or 37.6 per cent, are known to be dead, 61 patients 2 of whom were moribund on admission and

could not be operated on or 32.3 per cent, died as a result of their disease and 10 patients died from other causes but were free from tumor. Transurethral resection has effected cure in a good number of cases up to three and four years. The results for segmental resections have been somewhat more disappointing than Milner expected in view of the care with which these patients have been selected for operation. Results from total cystectomy have been uniformly bad. 3 patients were operated on and no cures were accomplished. This however, in Milner's opinion is not the fault of the operation but rather of the selection of cases.

Barnes, Turner and Bergman²¹ state that tumors of the bladder more than 5 cm in diameter and those situated in the ventral portion of the dome of the bladder should be removed at open operation otherwise endoscopic electrosection and fulguration are the methods of choice. A thorough removal of tumor tissue can be accomplished through the endoscopic approach because the tissue can be examined minutely and thoroughly through the lens system of the instrument and a distinction between tumor tissue and vesical muscular tissue can be made. From this observation it can be determined whether all the tumor tissue has been removed. There is danger of cutting entirely through the vesical wall and extravasation of urine into perivesical tissues may result when the endoscopic approach is used but the danger is minimized when the surgeon is familiar with the difference in appearance of the tissues.

During the past five years the authors have been using radon emanation seeds implanted into the area where the tumor previously was after endoscopic electrosection and fulguration for treatment of lesions of grade 2 or more of malignancy. The usual time of implantation of the seeds is four weeks after resection and fulguration of the growth. By this time most of the desiccated tissue has sloughed away and a deeper more accurate implant is possible. One and five-tenths millicurie seeds are placed about 0.5 cm apart throughout the tumor-bearing area of the vesical wall and are embedded about 1 cm deep. In most cases the implantation is done through the cystoscope and if this is performed correctly it is as accurate as when the open suprapubic approach is used.

and the results of treatment are superior to those obtained in the group of cases in which it was not used

The study also shows that the higher the grade of malignancy of the vesical tumor, the poorer the prognosis, and that in general the results of the use of radon seeds in the more malignant tumors are not as good as when used in the grade 2 tumors

Muellner²² states that cancer within a diverticulum of the bladder cannot be looked on as a rarity and must be regarded as a possible menace in all cases of large diverticula of the bladder. This point needs to be stressed, since in most cases the cancer within the diverticulum produces no specific symptoms whatever. Hematuria which is predominantly associated with it usually is explained erroneously on the basis of associated prostatism or infection. The cavity of a large diverticulum cannot be explored by cystoscopic means. Moreover, cystograms only rarely reveal cancer thus situated. In most instances, therefore, the cancer within the diverticulum can be discovered only by digital exploration when the bladder is opened surgically. A safe course is to explore surgically all large diverticula of the bladder, to excise them whether they are found to be free of tumor or not and to deal with the obstructing prostate by means which suit the individual surgeon best. In this manner, tumor-bearing diverticula are dealt with early and the insidious and eventual development of cancer within them is prevented.

Wilhelm²³ reviews 15 consecutive cases in which total cystectomy was performed. There were no operative deaths.

In the first 8 cases operation was done through a suprapubic abdominal incision with bilateral cutaneous ureterostomy in one stage. None of these patients lived much more than two years, nor did any lead a comfortable life after this operation. Three who died had distant metastasis or residual neoplasm in the stump of the prostate and urethra, 5 died as the result of renal infection and uremia.

In operation on 6 male patients the combined perineoabdominal method with implantation of the ureters into the sigmoid colon was used. Five of the men were living comfortably and were able to void through the rectum with normal control when the report was made. The 1 remaining patient, who had an advanced carcinoma, survived the operations but died five months later as the result of a large residual carcinoma.

The operation is done in two stages at the first, the right ureter is implanted extraperitoneally into the sigmoid colon, at the second stage,

22 Muellner, S R. Cancer in Diverticulum of the Bladder. A Pitfall to the Resectionist, *J Urol* 56:427-428 (Oct) 1946

23 Wilhelm, S F. Total Cystectomy by the Combined Perineoabdominal Method, *Surg., Gynec. & Obst* 84:90-96 (Jan) 1947

the bladder, seminal vesicles, prostate and posterior portion of the urethra are removed in one piece through a combined perineoabdominal incision, and the left ureter is implanted extraperitoneally into the sigmoid colon.

In males, preliminary mobilization of the urethra, prostate and vesical neck through the perineal incision simplifies greatly the subsequent suprapubic excision of the bladder.

The combined perineoabdominal method of total cystectomy is recommended for use in cases of infiltrating carcinoma of the vesical neck and trigone in which the patients are men because it permits truly radical excision of the bladder together with the attached posterior urethra, the entire prostate and the seminal vesicles.

Kleiman²⁴ discusses massive bladder implants resulting from carcinoma of the renal pelvis and reports a case.

The patient in his case was a man aged 50 years who had undergone nephrectomy on the left side and subsequent high voltage roentgen therapy two years earlier for treatment of a tumor. Ureterectomy was not performed. The large tumor had obstructed the renal pelvis and microscopically had been found to be papillary carcinoma.

On cystoscopy a large villiform papillary infiltrating tumor was noted. It extended from the left trigone and post-trigonal region to the internal urethral orifice and invaded well beyond the midline. A complete cystectomy was performed. The prostate, seminal vesicles, vas deferens and ureteral stump were also removed. No evidence of any extension from the bladder into neighboring structures was found. The entire mucosa of the bladder was involved by numerous papillary cauliflower-like growths comprised of firm gray tissue. Its wall showed evidence of extensive infiltration and in places measured up to 1.8 cm in thickness.

Tumors of the renal pelvis occur much less frequently than those in the parenchyma. The former are usually malignant and pathologically resemble tumors of the bladder or ureter. Most commonly they arise in the mucous membrane of the pelvis and calices. These comprise the papillary and nonpapillary epithelial tumors.

chronic infection Hematuria, the most frequent symptom, may or may not be associated with passage of blood clots Papillary growth tends to bleed sooner than the less vascular infiltrating tumors

The treatment of choice for papillary carcinoma of the renal pelvis is complete nephroureterectomy including excision of the vesical wall adjacent to ureteral meatus Papillary tumors of the renal pelvis have a great tendency to recur in the bladder following partial nephrectomy

The prognosis is particularly unfavorable when the renal parenchyma and perirenal fat are involved In cases of nonpapillary tumors whether operation is performed or not, the patient usually dies within a year The scirrhouous type of carcinoma metastasizes early and offers a grave prognosis The papillary tumors offer the best prognosis if diagnosed early, providing complete nephroureterectomy is performed

Neurogenic Changes—Mullenix²⁵ reports on the use of cystometry and states that it has been of great value in outlining management in a large number of cases of neurogenic bladder due to wounds of the spinal cord and cauda equina. He states that repeated cystometric study is the most important diagnostic aid in the urologic study of the neurogenic bladder and it provides a permanent graphic record of progress over a period of time By Mullenix' technic of cystometry the passive resting pressure and the active voiding pressure respectively for each hundred cubic centimeters of increment to contents of the bladder is recorded He thereby obtains a graph displaying the difference between active and passive pressures which represents the expulsive force, this difference is shown by a third curve on the graph called the voiding potential He found that in those cases presenting a wide difference between the passive and active pressures patients usually were able to void, while in those in which the passive pressure approached, and occasionally equaled, the active pressure patients were never able to void Thus a choice between performing cystostomy early and leaving an indwelling urethral catheter in place for a time is made more easily

Bumpus, Nourse and Thompson²⁶ report the urologic complications observed in 101 cases of injury or disease of the spinal cord occurring among United States Navy personnel

The most frequent urologic complication of injury of the spinal cord is the so-called cord bladder In 56 cases this vesical dysfunction followed gunshot or shrapnel wounds In 34 it resulted from fractures of the spinal column Among 11 other cases, the vesical paralysis was the result of tumors of the spinal cord in 2, followed inflammatory disease

25 Mullenix, R B Cystometry in the Study of Traumatic Neurogenic Bladder, J Urol 55: 470-482 (May) 1946

26 Bumpus, H C, Jr., Nourse, M H, and Thompson, G J Urologic Complications in Injury of the Spinal Cord, J A M A 133: 366-369 (Feb 8) 1947

in 5, developed insidiously after the patient had spent eighteen months in a Japanese concentration camp in 1 (probably from a dietary deficiency), was associated with myelodysplasia in 1 and a protruding intervertebral disk in another and was the aftermath of spinal anesthesia in 1

The height of the lesion in the cord has a distinct bearing on the urologic complications. Lesions above the conus medullaris, where physiologists and neurologists consider the mechanism of the bladder reflex to be (anatomists consider the mechanism to be close to the eleventh and twelfth thoracic vertebrae), involve the pathways of inhibitory impulses from the higher centers. Injuries which occur at the conus or below, in the cauda equina, do not interfere with these inhibitory tracts but damage only the reflex arc.

Perhaps of more importance than the level of the lesion is whether it is complete or incomplete. The sparing of nerve tracts and late recovery of the ability to transmit impulses account for unpredictable improvement in many cases.

In the great majority of cases two types of neurogenic vesical dysfunction were demonstrable. There was either an automatic or a reflex type of bladder, in which the lesion was, as a rule, above the tenth thoracic vertebra, or a retention bladder with overflow incontinence, in which the injury was usually below the tenth thoracic vertebra and generally involved the cauda equina.

The type of dysfunction which is caused by lesions low in the spinal column that usually involve the cauda equina is the most responsive to transurethral resection. Examination through the cystoscope shows various degrees of relaxation of the neck of the bladder. In some cases the region of the internal urethral orifice is constricted so that the bladder and dilated prostatic urethra have an hourglass appearance. In some cases, a bar type of deformity and in others an appearance like that of the vocal cords are seen. In all cases the vesical wall is trabeculated.

In cases of cord bladder, enough tissue is removed from the entire circumference of the vesical neck to make a definite funnel of the prostatic urethra. Postoperative retention depends as after prostatectomy on the external sphincter. To make this funnel requires the removal of but a small amount of tissue. If the first resection does not produce the desired effect, multiple operations are indicated, although the total amount of tissue excised seldom exceeds 10 Gm. In 16 cases of this series multiple resections were employed. Of 39 patients whose injury was at or below the level of the eleventh thoracic vertebra and for whom transurethral resection was performed 36 could urinate voluntarily when the report was made. Each could empty his bladder completely by straining, could sleep through the night without voiding and was continent. Each could tell when his bladder was full although the sensation which he described is not normal—a dull ache or heavy feeling in the lower part of the abdomen.

Transurethral resection has been of much, though less, benefit in cases of lesions high in the spinal column in which automatic or reflex dysfunction has been established but function is inefficient in that the bladder does not empty completely. Thus reflex stimulation might occur when the bladder contains 400 cc of urine and voiding takes place. If, however, 200 cc of residual urine remains after voiding, one must class this as an inefficient type of automatic bladder. The patient is deprived of the full reservoir function of the bladder. If, in some way, the bladder can be made to empty completely, the interval of time between reflex urinations can be doubled. In 19 of these cases transurethral resection diminished or entirely abolished the amount of residual urine, and in almost all cases in which previously it had been impossible to free the urine of infection the urine became crystal clear and finally free of pathogenic organisms. Resection in such cases did not produce incontinence. To the contrary, it tended to relieve it.

Until such time as the bladder has recovered whatever emptying and retaining function it is going to regain after the initial injury, the question of drainage is paramount. In the first few weeks following injury the use of a urethral catheter, if it can be properly maintained, is the easiest method of caring for vesical drainage. In cases in which drainage will be necessary late into convalescence, suprapubic drainage is preferable. To increase the capacity of the bladder and to try to overcome its spasticity, tidal drainage is used early in convalescence.

A total of 58 patients were treated by transurethral resection, in 57 cases the operation was successful, but in 1 case the result was total failure. Only 6 patients are now dependent on catheters, 93 can pass urine without mechanical assistance of any kind. Of this number, 53 have a voluntary type of urination, while in 40 it is automatic.

Emmett and Dunn²⁷ discuss transurethral resection in the surgical management of cord bladder. Cord bladders are characterized by (1) increased tone of the bladder with trabeculation, (2) presence of residual urine and (3) "active" incontinence. Inefficient vesical contractions result in intermittent urination which varies from frequent spurts of small amounts to sudden precipitate evacuations at reasonably long intervals of larger volumes of urine. The inefficient vesical contractions are unable to overcome the obstruction completely because of the spasticity of the vesical neck, and residual urine is the result. Removal of this obstruction of the vesical neck should therefore tend to eliminate the residual urine.

One characteristic type of cystoscopic appearance of the true cord bladder is the more or less constant "writhing" appearance of the bladder, which appears to be constantly undergoing irregular contractile

27 Emmett, J. L., and Dunn, J. H. Transurethral Resection in the Surgical Management of Cord Bladder, *Surg., Gynec. & Obst.* 83: 597-612 (Nov.) 1946.

The interureteric bar at times is enlarged to a tremendous degree, and is definitely obstructive. Cautious removal of this bar and some of the hypertrophic vesical wall near the vesical neck (often in the anterior quadrant) may be necessary.

The writers report the results with transurethral resection in 30 cases of cord bladder as follows: good, 23 cases; improved, 4 cases; fair, 2 cases; poor, 1 case. They conclude that cord bladder is no longer a hopeless situation and that satisfactory vesical function can be restored by mechanical adjustment of the vesical neck through transurethral resection and by teaching the patient to use unaffected muscles to aid him to void.

Miscellaneous.—Frost²⁸ discusses urinary incontinence in the female and states that while it may be a separate entity it is most commonly associated with urethrocele or cystocele and also, at times, a downward rotation of the urethra under the symphysis. In many cases there is relaxation of the vesical sphincter resulting in a combined cystourethrocele and a shortening of the urethra. Not all of these patients are incontinent, however, and Frost therefore believes that there are added factors including damage to the voluntary muscles of the urethra. The mere tightening of the neck of the bladder by plication and failure to correct the damaged urethral muscle may be the explanation of operative failures. Frost presents the following fundamentals for the surgical procedure in the correction of incontinence: (a) free mobilization of the bladder by its separation from the anterior vaginal wall, posteriorly from the cervix as far as the uterovesical fold, laterally until the vesicovaginal fascia is visualized as a smooth capsule and upward laterally under the pubic rami on each side to free the urethra, and (b) plication of the urethra and base of the bladder without tension from a point just below and lateral to the external urinary meatus and continued posteriorly to a point which includes the vesical sphincter. Thus the urethra is lengthened and the damaged voluntary muscle and relaxed sphincter are repaired. Added support to the urethra and bladder is created by means of strips of tissue excised from the anterior vaginal wall and sutured to the under surface of the symphysis and the vesical neck. The desired result is the restoration of the urethra, vesical sphincter and base of the bladder to their normal anatomic relationships.

PROSTATE

Neoplasms.—McCrea²⁹ states that there is no uniformity of opinion as to the best form or dosage of estrogens to be used in the treatment

²⁸ Frost, I. F.: Urinary Incontinence with Special Reference to Certain Factors Which Are Necessary in the Cure of This Condition, Am. J. Surg. 71: 172-179 (Feb.) 1946.

²⁹ McCrea, L. E.: Carcinoma of the Prostate. A Resume of Treatment with Ethinyl Estradiol. Preliminary Report, J. Urol. 56: 697-703 (Dec.) 1946.

The decrease in size of the prostate is remarkable in most instances following institution of the combined use of orchiectomy and estrogens. In this series of 15 cases, it has not been necessary to perform a single transurethral resection after the institution of combined therapy. When originally examined many of McCrea's patients had acute urinary retention. Drainage with an indwelling catheter was instituted. Within a month after orchiectomy without exception it was possible to remove the catheter, obviating the necessity of transurethral resection. Undoubtedly if this series were larger there would have been instances in which decrease would not have occurred and transurethral resection would have been necessary. It is further believed that certain types of prostatic carcinoma exist which respond differently to estrogenic therapy.

The breasts may become grossly enlarged and are sometimes painful. Such reactions are the exception rather than the rule. Kearns in a report on the use of the drug states that similar beneficial and untoward effects as well have occurred with ethinyl estradiol with the exception that there is definitely less stimulation of the breasts with the true hormone and possibly less gastric irritation. Not only is the tenderness of the breasts less likely to develop with estradiol but changing from stilbestrol to estradiol brings about diminution of the tenderness.

Edema of the lower extremities may be seen occasionally during estrogen therapy. The edema may be unilateral or bilateral and is usually not of great clinical importance.

Chase, Burt and Hess³⁰ report their use of orchiectomy in the treatment of carcinoma of the prostate in 54 cases. They state that inhibition of androgens by administration of estrogen is unsound because it is incomplete and that bilateral orchiectomy is the method of choice as basic treatment in prostatic carcinoma because it removes all of the androgens. The only exception would be in those cases seen early enough to do a complete perineal prostatectomy. Of their 54 patients, 46 were still alive, 4 were dead of irrelevant causes, 25 were fully employed and 6 received no benefit.

Nesbit and Plumb³¹ report on 795 cases of prostatic carcinoma diagnosed and treated at the University of Michigan Hospital between 1925 and 1940.

Comparative data at the present time indicate that survival rates are significantly increased by endocrine modifications in the series studied.

³⁰ Chase, D. W., Burt, K. L., and Hess, E. Orchiectomy in the Treatment of Carcinoma of the Prostate, *Am J Surg* 71:522-525 (April) 1946.

³¹ Nesbit, R. M., and Plumb, R. T. Prostatic Carcinoma. A Follow-Up on Seven Hundred and Ninety-Five Patients Treated Prior to the Endocrine Era and a Comparison of Survival Rates Between These and Patients Treated by Endocrine Therapy, *Surgery* 20:263-272 (Aug.) 1946.

Whether other or comparable series would show a similar advantage in favor of endocrine therapy can only be the subject for speculation, but the comparative survival rates among cases in which metastasis had occurred suggests that castration or estrogenic therapy has a beneficial influence on the survival curve.

Ormond³² discusses radical perineal prostatectomy for carcinoma of the prostate. He states that the criteria for selection of patients suitable for this operation are important. First and foremost, there must be no evidence of metastasis or extension. The prostate must not be fixed to the pelvic wall and there must be no induration at the apex of the prostate involving the membranous urethra. Some extension to the lower part of the seminal vesicle is not a contraindication. In most of the cases only a suspiciously hard nodule was present in one lobe. In a few the whole gland was hard when felt through the rectum. Roentgenograms did not reveal evidence of metastasis in any case and in all cases encountered recently the acid phosphatase of the blood was normal.

In view of the hopeless prognosis otherwise, the low operative mortality rate of the operation, the rarity of postoperative incontinence and rectovesical fistula and the fact that apparently the operation at least does not hasten metastasis even when it does not cure and does prevent recurrence of obstruction, Ormond believes the operation is useful and that it should be used more widely. A corollary to this is that members of the medical profession should be educated to recognize the condition early and that men past 50 years of age should have the benefit of a careful rectal examination every year.

Miscellaneous.—Berry and Miller³³ discuss regeneration of epithelium of prostatic urethra following resection. They examined patients after various intervals postoperatively and took sections for microscopic examination. These sections were obtained from a few days to three years after operation.

For the first two weeks after operation the prostatic cavity is covered with superficial slough and adherent mucus with a red surface showing through here and there. After from two to three weeks the slough has separated except where large tags of devitalized tissue are left and the prostatic cavity is clean, red and glistening except at the vesical neck, especially on the floor just below the trigone. Slough is still present at this point in many cases. Not infrequently after three weeks definite islets of epithelium can be seen in the prostatic cavity. At the end of a month the entire area should be completely healed.

32 Ormond, J. K. Radical Perineal Prostatectomy for Carcinoma of Prostate. *Surgery* 20: 257-262 (Aug.) 1946.

33 Berry, N. E., and Miller, J. Regeneration of Epithelium of Prostatic Urethra Following Resection. *J. Urol.* 56: 223-227 (Aug.) 1946.

Microscopically, there is first superficial necrosis and sloughing with infiltration of inflammatory cells followed by the development of granulation tissue. During this period there is proliferation of the epithelium in the ducts and acini near the surface and metaplasia to the transitional type, the acini at times becoming completely filled. About three weeks after resection, epithelium can be seen spreading out onto the surface of the new granulation tissue. This takes place from a large number of points, and consequently epithelialization is completed rapidly, usually within a month.

The postoperative course in these cases follows closely what one would expect from a study such as this, that is, frequency, pyuria and irritation are present during the period when slough is separating and there is an inflammatory process on the surface. Either separation of slough or trauma to the delicate new granulation tissue would account for bleeding. After three weeks, when the new epithelium begins to cover over, all these symptoms begin to subside. Ordinarily after a month healing is complete and the patient would be expected to be free of discomfort. It is only then that one would expect the pyuria to begin to clear up, and it usually does. This process of healing progresses with marked regularity, though infection and encrustation may delay its completion.

URETHRA

Traumatic Injuries—MacLean and Gerrie³⁴ present a method for the repair of wounds of the perineal portion of the urethra in which split thickness skin grafts are used. The results in 2 cases are described.

Skin cut from the bicipital region of the left arm with the Padgett dermatome at a calibrated depth of 0.015 inch (0.0381 cm) was used to build a tube around an inflated intratracheal cuff drawn over a two way Foley bag catheter. By inflating the cuff slightly, it was possible to build this portion of the urethra to a much larger caliber than normal, thus allowing in advance for shrinkage as healing and the surrounding fibrosis became complete. Multiple holes were also cut in the intraurethral portion of the catheter so that irrigation of the anterior portion of the urethra could be carried out, if desired, without disturbing the graft. The features of a skin graft considered to be desirable are (1) hairless skin with as few glandular or accessory skin structures as possible, (2) soft, pliable skin, (3) skin with a limited amount of elasticity to minimize the constricting action on the urethral channel, and (4) a thin graft to enhance the probability of take. By using a perineal exposure the tube graft can be placed in the exact position desired. The urinary stream was diverted by suprapubic cystostomy.

³⁴ MacLean T T, and Gerrie, J W Repair of War Wounds of the Bulbous and Membranous Urethra Using Split Thickness Skin Grafts and Penicillin, J Urol 56 485-497 (Oct) 1946

testicle and cord were later found on the left side. The phallus was well formed, devoid of urethra and did not represent an enlarged clitoris. Androgen and estrogen assays revealed a preponderance of female hormones.

Injections of testosterone propionate were utilized and produced marked secondary sex changes.

De Moura and Basto³⁸ present a case of true hermaphroditism in which the patient had a normal penis, with a testicle, epididymis, seminal vesicle and prostate and was able to secrete sperms. Besides, the patient had a uterus, functionally active ovary and monthly bleedings through the urethra. This is probably the first case in which the presence of a normal ovary and a normal testicle with presence of both ovules and sperms has been observed.

Inflammatory Conditions—Lewis³⁹ states that tuberculosis of the penis is a rare disease. In the literature 110 cases have been reported. In 72 the condition resulted from ritual circumcision, leaving 38 cases in which the condition resulted from other causes.

The disease may be primary or secondary, primary when no other endogenous focus can be demonstrated or secondary to foci either in the lung or genitourinary tract or both. Treatment has been rather unsatisfactory and the prognosis unfavorable. Five cases are reported from the Brady Urological Institute. In 3 the condition was primary, and in 2, secondary.

A hypothesis as to the mode of infection in so-called secondary infection is reiterated. According to this hypothesis secondary infection in most cases results from reinoculation through coitus.

Neoplasms—Lenowitz and Graham⁴⁰ state that, in general, carcinoma of the penis is of low grade malignancy. If it is diagnosed early and proper surgical treatment or irradiation is instituted, the results would compare favorably with those obtained in treating carcinoma of the exposed skin surfaces of the body. It is also a slowly growing tumor, and many years may elapse before the discomfort caused by the tumor causes the patient to seek medical aid.

Carcinoma of the penis may be mistaken for a chancre, chancroid, tuberculosis, balanitis, herpes progenitalis, gummatous ulceration or granuloma inguinale. A biopsy of all penile tumors should be performed to avoid error in diagnosis.

38 de Moura, A C, and Basto, L P True Hermaphroditism, J Urol 56 725-730 (Dec.) 1946

39 Lewis, E L Tuberculosis of the Penis A Report of Five New Cases, and a Complete Review of the Literature, J Urol 56 737-745 (Dec.) 1946

40 Lenowitz, H, and Graham, A P Carcinoma of the Penis, J Urol 56 458-484 (Oct) 1946

cases increasing phimosis with marked discomfort leads the patient to believe that circumcision is necessary for relief

Carcinoma of the penis is treated by roentgen therapy or surgical means or a combination of these methods. A lesion 2 cm or less which does not involve Buck's fascia is treated entirely by irradiation. The response to irradiation should be as good as that obtained in treating cancer of the skin of similar extent of involvement. Roentgen therapy is used (1) as the sole method of treatment in an attempt to cure the patient, (2) as preoperative irradiation preliminary to surgical intervention and (3) as palliative treatment.

Larger lesions involving Buck's fascia or the cavernous bodies are at the present time best treated by roentgen therapy and operation. Simple amputation is advisable whenever part of the organ can be saved. As in surgical treatment of tumors elsewhere in the body, wide excision of the neoplasm must be the aim to prevent recurrence. When the lesion is too extensive and part of the organ cannot be saved, total extirpation of the penis is the operation of choice. Metastatic or suspicious nodes should be treated by irradiation after block dissection. It is best to treat unilateral involvement of the groins as though bilateral involvement were present in order to prevent recurrence. Emasculating operations are indicated only when the scrotum is invaded by the neoplastic growth.

Lenowitz and Graham performed major operations on 82 patients who had carcinoma of the penis and present a thorough discussion of several surgical procedures used.

TESTES

Traumatic Injuries—Ockuly⁴¹ reports a case of traumatic dislocation of the testis. The patient was a 24 year old soldier. Ockuly states that to date only 71 cases of true dislocation have been reported in the literature, and defines the condition as the displacement of a previously normally located testis to a nonscrotal position by being forcibly propelled through normal anatomic apertures or along fascial planes the integument of the body remaining intact. Displacement may be to the superficial fascia of the lower part of the abdomen, dorsum of the penis, perineum, crural area of the thigh, inguinal canal, femoral canal or abdominal cavity. If nonsurgical replacement is impossible, early surgical treatment is indicated.

Inflammatory Conditions—Nixon and Lewis⁴² discuss orchitis due to mumps and its surgical treatment. Orchitis usually occurs before the

41 Ockuly, E. A. Traumatic Luxation of the Testis, Am J Surg 71:93-95 (Jan.) 1946.

42 Nixon, N., and Lewis, D. B. Mumps Orchitis—Surgical Treatment, J Urol 56:554-560 (Nov.) 1946.

complete subsidence of the parotitis. In rare instances it may precede the parotitis by a number of days and in other cases may be the only manifestation of mumps. Occasionally orchitis will occur three to six weeks after the onset of parotid swelling.

The patient's temperature curve is helpful in diagnosis, both in the early stage and in the subsequent course of testicular involvement. The temperature usually rises shortly before the patient begins to complain of testicular tenderness. As swelling occurs the temperature goes higher sometimes to 105° F. and the patient complains of chilliness, headache, malaise, nausea and vomiting. The testis becomes hard, smooth and exquisitely tender and remains so for at least four or five days. The temperature then drops by lysis and swelling subsides. The usual duration of the orchitis is about ten days. In some cases especially those in which orchitis develops more than fourteen days after the onset of parotitis general symptoms are few. The pathologic picture is one of accumulation of hydrocele fluid between the tunica vaginalis and the tunica albuginea which may result in pressure necrosis of the seminiferous tubules with subsequent partial atrophy of the testes.

Nixon and Lewis used the following surgical procedure for treatment in 66 cases of orchitis due to mumps. After infiltration of a 2 per cent solution of procaine hydrochloride a small incision approximately 2 cm long is made over the anterior surface of the scrotum on the involved side. The incision is carried through the skin and subcutaneous tissues until the tunica vaginalis is exposed. This is grasped with two Allis clamps and incised. Usually the hydrocele fluid drains out under considerable pressure. A small Penrose drain is inserted beneath the tunica vaginalis and the wound is closed. After operation most patients reported immediate alleviation of extreme pain and discomfort. Others showed improvement within two to four hours with relief not only from pain but from headache, nausea and vomiting as well. Within twenty-four hours the local swelling was considerably reduced and the testis could be palpated with little discomfort to the patient. Drainage was maintained for at least twenty-four hours.

A coplasma—Goodwin¹³ discusses multiple benign fibrous tumors of the tunica vaginalis. Examination reveals a scrotal mass which is extratesticular and extends upward from the upper pole of the epididymis and may seem to originate in the cord or the epididymis. The tumor is multinodular and fibrous, nearly stony hard, yet apparently freely movable. It may suggest a calcified varicocele, and roentgenologic examination may sometimes reveal small areas of calcification within the mass. In the event of much thickening of the tunica vaginalis or associated

43 Goodwin, W. E.: Multiple, Benign Fibrous Tumors of Tunica Vaginalis Testis, J. Urol. 56: 438-447 (Oct.) 1946.

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⁴³ Goodwin, W. E.: Multiple Benign Fibrous Tumors of Tunica Vaginalis Testis, *J. Urol.* **56**: 438-447 (Oct.) 1946.

hydrocele the mass may seem to be a part of the testis or epididymis and may then definitely suggest a malignant lesion of the testis. The correct preoperative diagnosis is made only about half of the time, this is probably due as much as anything to the rarity of the condition.

Operation is indicated as it is in the case of any intrascrotal mass in which malignancy must be ruled out. Careful inspection of the tumor at operation, however, is mandatory, for there is a good chance that an extratesticular tumor is benign, and unnecessary orchectomy is unfortunate indeed. Simple excision of the tumor and possibly the epididymis, with which it often lies in close contact, is indicated if the mass is obviously benign. If there is any question, biopsy and, if necessary, orchectomy should be carried out.

Grossly the tumor has a typical fibroid appearance and is covered with a smooth, glistening membrane, probably the tunica vaginalis. It looks like typical multiple fibromas elsewhere in the body. Microscopically one sees whorls of fibrous tissue and a few typical spheroids. There is thickening of the vessel walls, and some portions present hyalinization and even calcification. There are frequent scattered areas of focal lymphocytic infiltration and some plasma cells indicating chronic inflammation.

Goodwin suggests that the term "chronic proliferative periorchitis" be reserved for simple chronic inflammatory thickening of the testicular tunics, and that multiple fibrous nodules which appear separate from the testes, and apparently originate in the tunica vaginalis, retain the clinically more acceptable term of "multiple fibromata" even though they may show marked inflammatory changes and may represent the same disease process as "chronic proliferative periorchitis."

Goodwin and Vermooten⁴⁴ present 2 cases of multiple fibromas of the tunica vaginalis. It is felt that these tumors may really represent a proliferative type of chronic periorchitis. The clinical diagnosis in these cases, because of the rarity of the condition, is seldom correct preoperatively, in spite of the fact that the physical findings are so definite and characteristic that once having seen such a nodular tumor, one would not be likely to err a second time. In reports of several of these cases which the writers have collected, the testis was removed needlessly because the benign nature of the tumor and its origin were not recognized at or before operation. It certainly behooves the surgeon to make careful preoperative examination and in cases of doubt to await the microscopic examination of a biopsy specimen, taken at the time of operation, before performing orchectomy. The treatment is and always must be surgical, even in known tumors of the tunica vaginalis.

⁴⁴ Goodwin, W. E., and Vermooten, V. Multiple Fibromata of Tunica Vaginalis Testis or a Proliferative Type of Chronic Periorchitis. A Report of Two Cases, J Urol 56:430-437 (Oct.) 1946.

Nesbit and Lynn⁴⁵ studied 80 cases of malignant tumors of the testis and found that the survival rate in the entire group was 23.8 per cent. In 33.3 per cent of 51 cases in which metastasis was not demonstrable the patients were alive after an average of eleven years. They found that an occasional cancer of the testis which had metastasized can apparently be cured by orchietomy and roentgen therapy. The average age in the group of cases reviewed was 35.7 years and the average duration of symptoms was twenty and five-tenths months. Occasionally testicular neoplasms exhibit an acute onset resembling epididymitis or acute hydrocele. They found only 33.5 per cent of 54 cases displayed significantly elevated gonadotrophic levels. The titer of gonadotropin should be at least 500 mouse units before the test is considered significant. A negative result of the test for gonadotropin means nothing, however, a positive response dictates a grave prognosis. In certain cases in which metastasis occurs following treatment results of the hormone test may be positive when they had been negative before therapy. Once adequately treated, the patient will either survive or perish, and no further endeavor on the part of the physician will alter the outcome significantly except in rare instances. Metastatic lesions which fail to regress or which become clinically evident following initial irradiation will not respond favorably to additional high voltage.

In a study of 922 tumors of the testis, Friedman and Moore⁴⁶ classified 96 per cent of such new growths as seminoma, embryonal carcinoma, teratoma or teratocarcinoma.

Seminomas and embryonal carcinomas are distinct tumors which differ not only in fundamental cell type but in biologic behavior and prognosis. Chorioepitheliomas are considered a subvariety of embryonal carcinomas. The term "teratocarcinoma" is applied to those tumors which show both differentiated teratoid structures and malignant elements and are thought to result from teratoid differentiation in embryonal carcinomas. Monocellular testicular neoplasms ordinarily do not originate from preexisting teratomas.

Virtually all embryonal carcinomas metastasize as monocellular embryonal carcinomas, but choriomatous characteristics may be evident in the metastatic lesions of embryonal carcinomas or teratocarcinomas even when they are not manifest in the primary tumor. Roughly half of the teratoid neoplasms which metastasize give rise to growths with teratocarcinomatous structures and half to pure embryonal carcinomas.

45 Nesbit, R. M., and Lynn, J. M. Malignant Testicular Neoplasms Analysis of Eighty Cases, *Surgery* 20:273-279 (Aug.) 1946

46 Friedman, N. B., and Moore, R. A. Tumors of the Testis. A Report on Nine Hundred and Twenty-Two Cases, *Mil. Surgeon* 99:573-593 (Nov.) 1946

Immediate prognosis is bad in cases of embryonal carcinoma and chorioepithelioma and poor in cases of teratocarcinoma and adult teratoma, which should be regarded as matured teratocarcinomas. In cases of seminoma, in comparison with the other testicular tumors, the immediate prognosis is good.

The architecture of testicular tissue is not reproduced in seminomas, and the neoplastic cells do not resemble spermatogonia. Seminomas are probably tumors of primordial germ cells and should be called germinomas. Embryonal carcinomas and teratoid tumors, which are composed of evolving and differentiating somatic and trophoblastic tissues, are neoplastic expressions of the unlimited potencies of embryonic cells.

Miscellaneous—Huhner⁴⁷ outlines a procedure for aspiration of the testis for spermatozoa. A few drops of tincture of iodine is applied to the skin at the proposed site of puncture, and a long needle attached to an ordinary hypodermic syringe is plunged through the entire body of the testis and epididymis, and suction is applied as the needle is withdrawn slowly. A small amount of collodion is applied after the needle is withdrawn. No anesthetic is used, and the patient may resume his ordinary work within a half hour after the procedure.

In the examination of the aspirated fluid, two precautions must be observed. In the first place it is important to put the point of the needle directly on the slide and express the fluid. If air is first expelled from the needle, as is the custom in ordinary hypodermic methods, all or most of the spermatozoa may be lost, for they seem to stick to the very point of the needle, and the second precaution is to look for a long while, sometimes as long as an hour or until all the aspirated fluid has been examined.

This method is purely for diagnosis, to answer the question of whether the testis makes spermatozoa or does not or, in other words, to determine whether epididymovasostomy is worth trying.

Huhner believes that aspiration is superior to biopsy because with the latter conclusions are drawn from the examination of only a small portion of one or both testes, and biopsy of various portions of the same testis yields different results.

EPIDIDYMIS

Neoplasm—Codnere and Flynn⁴⁸ report 3 cases of adenomatoid tumors of the epididymis.

Adenomatoid tumors of the epididymis are globular or oval in shape, less than 2 to 3 cm in diameter, sharply circumscribed and encapsulated.

47 Huhner, M. The Investigation of the Spermatogenic Function of the Testicles in Cases of Azoospermia, *J Urol* 56:266-268 (Aug) 1946.

48 Codnere, J. T., and Flynn, J. E. Adenomatoid Tumors of the Epididymis Report of Three Cases, *J Urol* 56:448-453 (Oct) 1946.

The cut surface is firm and white to gray. Microscopically, these tumors consist of a fibrillar stroma in which are embedded tubular-like structures lined by cuboidal to flattened cells having prominent dark-staining or vesicular nuclei and acidophilic cytoplasm.

On the basis of histologic similarity, aberrant mesonephrogenic structures are thought to constitute the genetic foundation of these neoplasms.

Bothe, Cristol and Devers⁴⁹ state that tumors of the epididymis, while more rare than solid tumors of the testes, are less frequently malignant. Two cases of epididymal tumors are presented in which accurate diagnosis was not made until after an exploratory operation and cytologic study.

Benign tumors are found to constitute approximately 30 to 40 per cent of all tumors of the epididymis. The myoma appears to be the most frequently found variety of this rare group of benign growths.

As with testicular neoplasms, tumors of the epididymis rarely cause symptoms. Their presence is detected when trauma directs the attention of the patient to the scrotum or when the physician carefully examines the scrotal contents. Since many of these tumors cannot be definitely separated from the testes on physical examination, the treatment of epididymal masses resembles the treatment for testicular masses. Any patient who has an intrascrotal solid mass deserves surgical exploration. The subsequent treatment will depend on the location and the nature of the mass found. In the case of benign epididymal lesions removal of the mass together with the associated epididymis will suffice.

GENERAL

Melick⁵⁰ discusses the advantages of cotton as a suture material in urologic operations, including scrotal, ureteral and renal operations. He states that uniformly excellent results have been obtained without formation of a chronically draining sinus. No 80 cotton is used for the ligation of all ordinary bleeders, while for large vessels either catgut or a larger gage of cotton suture was used. No 80 cotton is also used to close all layers of scrotal incisions. No 30 or 40 cotton is used in approximating muscle and fascial layers. Multiple fine interrupted sutures are used, the stitches being placed about 0.5 cm apart and only small amounts of tissue being included in each stitch. Correct technic is practically forced on the surgeon with these sizes of cotton, since if too much tissue is included in each bite the suture will break when an attempt is made to tie it. Renal incisions are closed by

49 Bothe, A. E., Cristol, D. S., and Devers, P. J.: Benign Tumors of the Epididymis, *J. Urol.* **56**: 710-714 (Dec.) 1946.

50 Melick, W. F.: The Advantages of Cotton as a Suture Material in Urological Surgery, *J. Urol.* **56**: 602-608 (Nov.) 1946.

suturing the posterior, middle and anterior layers of the lumbodorsalis fascia separately, and the muscles are not sutured. In closure of a ureterotomy incision, the muscles are approximated loosely and then the external fascia is closed. The skin is approximated with either vertical mattress sutures of no. 30 or 40 cotton or with a running, interlocked suture similar to the one made with the Singer machine. There is practically no difference in time required to place either of these, however, the running suture, so made, has the additional advantage that it may be removed completely merely by cutting off the knot at both ends, and with one pull the entire suture line is removed.

The majority of the wounds repaired with cotton sutures in this series were drained. Scrotal wounds were drained for from one to four days, the average being two days, with small strips of rubber dam drain. In cases of renal and ureteral operation the wounds were drained four days with a large strip of rubber dam drain. Since in cotton there is no loss in tensile strength for ten days, and then only a slight loss in the following days, these patients may be allowed out of bed just as soon as their general condition permits. Patients who have undergone scrotal operations sometimes are up walking around on the first postoperative day. If the general condition permits in the other cases the patient is permitted to sit up in bed on the first two postoperative days, is out of bed in a chair on the third postoperative day and walks about with help on the fourth postoperative day.

There were no chronic sinuses, no extrusion of knots or sutures, no induration and no wound disruptions or postoperative hernias. The rapidity of healing, the lack of drainage and absence of infection are remarkable. Healing is rapid, clean and certain.

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PREPARATION FOR A MEDICAL CAREER

Presidential Address

CASPER F. HEGNER, MD

DENVER

EACH period of history of the human race had its characteristic medical status.

In the beginning the causes of illness and the means of their alleviation were based on the supernatural. The healers were mystics or conjurers.

The next period (400 to 500 B.C.) witnessed the development of philosophy and the dawn of scientific observation in the concept of disease. The devotees of the healing art made a study of man and his reaction to his environment. It was appreciated that these were important factors in the development and well-being of man.

Then followed a period during which the plan of separation was developed. A healer or a physician became interested in or treated a single disorder or a disease of a single organ or system. The human organism as a whole was overlooked in concentrating on a relatively small part. This is like the system of specialties today.

With the advent of bacteriology, science began to broaden and dominate the field of medicine. By establishing bacteria as the exciting or specific cause of disease many proved factors influencing the invasion and course of the disease as well as its epidemiology were overshadowed.

This was followed by the present laboratory era of medicine, in which laboratory facilities and technicians' reports bear the frontal attack and continue as major factors of the campaign in the study, diagnosis and treatment of disease. The host of the disease receives consideration secondary to the more spectacular local phenomena.

War has influenced and will continue to influence medicine in all its aspects, not the least being the tremendous if not excessive emphasis on specialization. Personal qualifications, premedical studies, medical, clinical and graduate teaching, intern, resident, hospital staff and group practice are destined to be vastly different. Private practice as of the past fifty years, during the period of greatest advance in medicine, will become legendary.

Read at the fourth annual meeting of the Central Surgical Association, Chicago,
Feb 21, 1947

The direction, speed and extent of these changes will depend largely on you men who have recently graduated. You are on the threshold of the greatest epoch in history. The present demands alert, young, well prepared, courageous men to mold the minds of students, to determine the teaching methods and the future trend of medicine.

You must be conversant with medical history and the traditions of the past. You must qualify as research workers, teachers, clinicians or practitioners. All must be sensitive to and active in the rising tide of politicoeconomic plans that may make or mar your individual and collective efforts for the best interests, welfare and service of mankind.

A neglected but increasingly important duty is to encourage students who are personally and scholastically qualified, who are interested in and wish to study medicine. Much can be done in guiding and advising in their preparation.

Selecting a vocation is one of the most important acts of a lifetime. Always perplexing, it has become more so with increasing complexities of modern living. Considering how uninformed one is when so momentous a decision is usually made it is remarkable so many make a fortunate choice.

Knowing what you want, and to want it with all your heart, is more than halfway along the arduous road to attaining your objective.

Knowing where and how best to prepare for one's ideal presents problems. In solving these one must depend on others with experience for guidance. The earlier one receives proper direction, the sooner and more thoroughly can one prepare for one's life work. The inception of this understanding should be in the home.

The modern American home has lost much of the character-building influence which it formerly enjoyed. The radio with its expert commentators make one indifferent in one's reading and thinking about the news and what makes it. Its excellent artists on special programs make one impatient with amateurs. Motion pictures are setting a comparatively low standard in taste and amusement. They divert one from evenings at home, dull one's interest in current events, friends, family and conversation.

Recorded music by master artists stimulates one's taste for the best, but discourages lesser professional musicians and many others.

This penchant for outside diversions is lessening the desire for self-improvement and companionship and is weakening the home influence which has been the bulwark of the American way of life.

It is in the home that character is built, that influences for good are strongest and the urge to accomplish and progress receives its earliest impulse. It takes time, personal energy, interest and sacrifice to build, strengthen and make an attractive home life and to foster the interests of the children. For them the home is paramount.

Every parent should have at heart and in mind the best interest and future welfare of all his children. He can sensitize them with a desire to learn and encourage them to think and to have consideration for others. He can sow the seeds of their future character.

All too early this important phase of child guidance and training is shifted largely, if not entirely, to the public schools. There the task is for the many. The unusual, the apt children are not carried forward. Facilities to advance them are not provided. The overcrowded rooms and the multiplicity of subjects confuse the children and hamper and overwork the teachers. Whatever their inclination they have no time to give to unusual pupils. A qualitative principle from the point of view of the teacher and the taught is more important than the quantitative plan which dominates the present educational program. The objective should be how thoroughly fundamental subjects can be instilled into the minds of pupils of the same average age and mental capacity with varying grades of receptivity.

High schools could develop a plan whereby pupils with greater aptitude and scholastic ability are grouped in classes and courses best suited to preparation for advanced education.

Education must be available for all from the lowest school grades up through the institutions of higher learning. More consideration should be given to the fact that all are not equally receptive of instruction, all do not develop with equal rapidity or in equal degree.

A system graded solely to the mental capacity of the average cannot give adequate instruction to the more receptive pupil. He, for want of the stimulus of competition, develops a sense of superiority and becomes indifferent, mentally lazy and a time waster. Conversely such a course is geared too high for the less than average pupil who needs more time and requires more instruction and attention than can be given him. He becomes acutely aware of his inability to keep up with his class, becomes discouraged, acquires an inferiority complex and falls farther behind.

The system of teaching with courses graded solely for the average pupil is wofully wasteful of time, effort, material and minds. It lowers the standard for all. It neglects the group from which the leaders of tomorrow are recruited.

A grouping in classes of pupils according to aptitude, scholastic ability and receptivity and arranging courses and type of instruction best fitted to the capacity of each group is efficient, economical, practical and progressive pedagogy.

This is vital for the candidates for professional, scientific and advanced education. By the time that students are ready for college there must be some indications that all are not equally capable or interested. Arranging courses and classes to coincide with the receptivity and mental capacity of the students is imperative in college.

The instructor by virtue of experience and intimate contact with students should be in a position to group students and to advise and outline courses best suited in preparation for the vocation of their choice

Thus may one's abilities be estimated, aptitudes discovered, interest aroused and efforts encouraged A future suited to one's capabilities, talent and desire can then be planned more intelligently

The virtue of study is to discipline the mind to think and to reason In direct ratio to one's ability to think will be one's status among one's fellow men Thinking opens unexplored realms of science and human relations and blazes trails of progress that others may follow Comparatively few medical freshmen known how to study or have ever been taught to think

The ultimate in education is to develop the minds of youth to the end that they may attain the greatest degree of personal happiness and efficiency in rendering the highest grade of service to society, i.e making the world a better place in which to live

A university to be effective supervises and trains students for the responsibilities of civic, business and professional life

Selection of students best suited to and qualified for advanced education should be an important function of college faculties Personal fitness, character, scholastic aptitude, ability and manners are important qualifications Worthy students should be financed by grants, scholarships, fellowships and residencies

There are no reliable short cuts or hurdles to a thoroughly grounded well balanced education It takes conscientious, continuing and concentrated study Recognizing one's limitations and taking timely appropriate measures to overcome them are duties never fully discharged

It is unusual in choosing medicine as a career to appreciate what such a choice involves the expense, years of preparation, long period of unremitting work and the lean years of getting established in practice All this the prospective medical student should know and be able to cope with cheerfully and patiently

I have always been interested in the reasons which prompted students to select a career in medicine Of the many interesting answers to this question only a few stated that it was a desire to be of service to humanity

The welfare of and service to humanity are the true motives for choosing a medical career Service is and always will be the abiding passion of the true physician

For the highest type of service, he must love his profession and mankind above all He must have physical, nervous and psychic stamina, possess a sense of humor, good manners, pleasing address and be honest, honorable, unselfish, patient, tactful, charitable and understanding Besides these personal qualifications he must be endowed with a receptive mind and a retentive memory, a scientific and scholastic aptitude spawned

in the home, developed in school and activated by a broad academic course Only on such a foundation can an eminently successful medical career be developed

There is no limit to improving one's self Perfection is unattainable, but one must keep on trying The pursuit of perfection in the service of mankind is the noblest ideal It is the activator of laudable human endeavor and the irrepressible stimulus to ambition The true physician is happy in this quest

Nothing matures like time Maturity develops experience and sympathetic understanding of human, spiritual, scientific and material values, the foundation of good judgment

Routine technic and operative procedures are comparatively easily taught Judgment and intuition, doing the right thing at the right time in the right way, cannot be taught so easily It must be acquired by experience, profiting as much, if not more, from one's failures as from one's success

To alleviate the miseries of mankind one must have a profound respect for the wisdom of the past One must know the natural history and course of disease This develops better understanding of the present, gives greater promise of the future control of disease

Masters of the past, with little to guide them but keen observation and logical deduction, pioneered many leads which on investigation with the scientific equipment of a later day became established facts

It is given to but few to discover a new procedure, a better technic or more potent remedy, the real cause of, or a specific cure for, disease

To learn the causes of illness, to know the factors for success and the reasons for failures of treatment is the ambition of all This is the province of the research worker in the laboratories and the clinical investigator in our teaching hospitals

Uncontrolled enthusiasm for the new and untried leads to unwarranted hopes and subsequent disappointment

All may put to practical test that which has given promise Record your experience, let neither enthusiasm of success nor discouragement of failure deter you from making a contribution to medical experience Of such is true progress made

Many of you are now, and some will continue to be affiliated with teaching institutions Teaching is a serious responsibility, a stimulating and valuable experience The most gratifying being to know you have been even in a small way responsible for the success of your students

Others fired by the spirit of service will go far afield from medical centers and ready to hand laboratory aids The larger duty of the members of the medical profession is to see that when and wherever services are required, there will be competent medical and surgical attendants Being well prepared and thoroughly trained one will give excellent service

and acquire a rich experience. From the far flung frontiers of medicine one can make important observations and valuable contributions scarcely second to the studies of classic, cloistered, scientific laboratory and clinical research workers.

The true science and study of mankind is man. The reaction of the human organism as a whole is no less important than is its local reaction to disease.

Jean Nicolas Corvisart (1755 to 1821), the first cardiologist and a great teacher, brusquely asked a student who came into his clinic what he came for. "To study, sir," replied the student. "Good," replied Corvisart and, pointing to the assembled patients, said, "there are your books, but they are not so easy to read as a printed book."¹

Comparative animal experiments and research are most valuable scientific procedures. These probe paths for progress in medicine. They can never fully replace clinical observation and research, which carry the seed and product of science to benefit the ill patient.

The art of medicine, clinical, comparative and scientific research are all important. They do not conflict but are correlated one with another. Progress can neither be made nor be maintained if one is divorced from another.

It takes different temperaments and qualifications to become a scientific investigator or a clinician. A truly scientific research worker is one for whom the quest of perfection, the solution of problems and the establishing of cold facts and irrefutable principles transcend all. A clinician searching for infallibility applies these facts and principles in the critical study and treatment of his patients and their disease.

A good clinician or practitioner must be patient, observant, tactful, versatile, charitable, understanding, honest, honorable and tenacious of the right. A surgeon in addition must have the spirit of a discoverer, the courage of the righteous, the heart of a champion and the judgment of a sage. He must be resourceful, considerate but still decisive, firm yet gentle and capable of executing all his manipulations with consummate skill and dexterity.

To acquire these necessary qualifications one must have contact with many patients of every variety. One must learn by observation and by the teachings of his superiors in hospital service. A rotating internship of not less than a year and a half in a good teaching hospital gives a wide experience with many patients in all phases of practice under supervision of a number of different instructors. This should be followed by a residency of not less than two years in a service of one's choice, in a teaching hospital preferably in an entirely different section of the country. This contact with new types of persons, new teachers, new

¹ Hinsdale, G. Our Medical Debt to France, Ann M Hist 4 154-166 (March) 1942

ideas and new environment has a decidedly broadening influence. The surgical resident should seek frequent advice and counsel of his fellow residents and staff members, especially in difficult cases, cases with confusing complications or in any circumstance that interrupts a smooth progress. A desirable habit of seeking advice thus formed and carried into private practice cannot but benefit him and may help the patient.

From a broad foundation in general medicine and the many contacts with various specialties and specialists during one's hospital training, one may, if so minded, select a specialty for which one is best qualified and which seems most attractive and interesting. The additional years of intensive training required for qualifying as a specialist has more than justified the prolongation of the training period.

The better basic training in general medicine, the more satisfying will be one's experience and the more acceptable one's service in any specialty. Whichever specialty one chooses, one never should lose the inspiring touch of general medicine. One should always keep the goal in mind, from which there should be no diversion.

The young surgeon should establish a reputation for dependability. He should cultivate the acquaintance of his colleagues. The better they know one another the better each will be, and the greater will be the respect for the medical profession. He should be a consistent attendant at medical society meetings, where he may learn or impart something of value to others.

In addition to your major interest in practice, become alert and active in the changing conditions under which that practice will be carried on. These changes, unless guided by you, may seriously or radically restrict the freedom under which American medicine has advanced beyond that of any other country at any time in history. No individual or group of individuals has more knowledge of the ills of humanity or knows better how to prevent or treat them than you. Keep abreast of these trends lest you be deprived of your vested right to serve suffering humanity and become subservient to a blighting political program which spells doom to the traditions of our proud past and our present well earned worldwide reputation.

Your society will secure and maintain a preeminent position if each one of you does his part and unstintingly supports his officers. Your society's main purpose is to become a forum for the free interchange of experiences and ideas that all may profit, be encouraged and stimulated to advance the knowledge and science of surgery.

With honesty and honor in your relations one to the other, with good preparation for your duties and earnest application, you cannot fail to reach heights beyond your fondest expectations.

GASTRIC ULCER FOLLOWING RADIATION

COLONEL FRANK E HAMILTON
MEDICAL CORPS, UNITED STATES ARMY

ULTRAHIGH voltage roentgen radiation is frequently used in the management of certain malignant growths. As additional tumor centers are constructed, the use of 1,000,000 volt, and even higher, radiation therapy will increase. Excellent results are being obtained after massive high voltage roentgen irradiation of radiosensitive malignant growths. However, at Walter Reed General Hospital it has been noted that after application of 1,000,000 volt radiation to retroperitoneal nodes in the region of the normal stomach an unusual secondary lesion may occur. Occasionally atypical gastric ulcer develops near the pylorus. The chief symptom is hemorrhage. Perforation has occurred. This condition has been reported elsewhere as a terminal phase of the malignant process. It is, however, usually amenable to surgical treatment.

Similar secondary effects are not new. Gastric ulcer was produced experimentally by Engelstad¹ after heavy irradiation of the normal stomach of rabbits. Hueper, de Carvajal-Forero² and others produced radiation ulcers in the normal dog stomach. Curling, Lee, Leonard, Weiskotten and Bardeen³ have all reported ulcers of the stomach and duodenum following cutaneous thermal burns.

PRESSENT STUDY

At Walter Reed General Hospital 256 radiosensitive malignant tumors of the testis were treated with 1,000,000 volt roentgen radiation.⁴ The present procedure is the application of a test dose of radiation to

From the Walter Reed General Hospital, Washington, D. C.

Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec. 6, 1946

1 Engelstad, R. B. The Effect of Roentgen Rays on the Stomach in Rabbits, Am J Roentgenol 40: 243-263 (Aug.) 1938

2 Hueper, W. C., and de Carvajal-Forero, J. The Effects of Repeated Irradiations of the Gastric Region with Small Doses of Roentgen Rays upon the Stomach and Blood of Dogs, Am J Roentgenol 52: 529-534 (Nov.) 1944

3 Curling, Lee, W. E., Leonard, Weiskotten, H. G., and Bardeen, C. R., cited by Bancroft, F. W. Cutaneous Burns, in Christopher, F. A Textbook of Surgery, ed. 3, Philadelphia, W. B. Saunders Company, 1942, pp. 60-68

4 Amory, H. I., Friedman, M., Greenfield, M. M., and Brick, J. B. Personal communications to the author

determine the sensitivity of the tumor, followed by radical orchiectomy. Later the retroperitoneal glands are given massive prophylactic irradiation. The proportion of clinical cures of the malignant growth is high—80 per cent for seminoma and 50 per cent for teratocarcinoma.

It was noted that when the radiation dose to the region of the normal stomach exceeded 5,000 r atypical symptoms of epigastric distress developed in about half the patients. The condition of most of these patients improved under treatment, in 35 of them a large, single gastric ulcer developed, as proved fluoroscopically.

The symptoms exhibited by these patients were atypical. The only constant symptom was epigastric distress, of varying degrees, first noted two to three months after completion of the roentgen irradiation. Some of the patients exhibited the complex of pain relieved by food usually associated with gastric ulcer. In some there developed rather severe epigastric pain with no relation to food. In some the first symptom was gastric hemorrhage, occasionally severe. The degree of gastric acidity was likewise atypical. In some patients the acidity was somewhat increased, in the majority it was normal, or even subnormal.

After medical treatment, most of the patients were clinically cured of the gastric ulcer and were discharged. Six required operation.

The first of the patients with radiation ulcer to be operated on had a proved gastric ulcer with minimal epigastric distress. Suddenly uncontrollable gastric hemorrhage developed. Col. Ralph Bowers, then chief of surgery, decided to attempt a palliative operation. He was unable to locate the exact position of the ulcer, so did a subtotal gastric resection. The patient made a complete recovery. Colonel Bowers then operated in 3 similar cases, with postoperative death in 1 case, no improvement in another and clinical cure in the third. Since that time I have operated in 2 additional cases of radiation ulcer, with clinical cure in both.

The operative observations in these cases are somewhat bizarre. The irradiated areas of skin over the retroperitoneal nodes are brown and leathery in consistency. This factor, however, does not interfere with postoperative healing. Intra-abdominally, there are greatly increased fibrosis of the irradiated tissues and, usually, increased vascularity. The stomach and jejunum has a brown, burnt-out appearance. The dome of the diaphragm is usually high, and the stomach appears to be pulled into a higher position than normal. The mesentery of the colon and jejunum appears to be shortened. The omentum is usually a small, burned-out shred of tissue. In addition, the affected portions of the stomach and jejunum have a smoothed-out appearance and are leathery in consistency, no peristalsis is visible.

In all these cases in which operation was performed the ulcer was located on the posterior wall of the stomach near the pylorus. Two of

the ulcers perforated prior to operation, and in both instances the ulcer perforated onto the pancreas, where the posterior wall of the stomach was so fixed by fibrosis that the perforation was completely encapsulated.

There has been a recent exception to the previous cases. A discharged officer was known to have a radiation gastric ulcer, which was practically asymptomatic. While he was at a seashore resort, a perforation occurred without warning. He was retained in a local hospital for forty-eight hours without operation and was then flown to Walter Reed Hospital. On arrival he presented the picture of generalized peritonitis. He was placed under supportive therapy, but the peritonitis did not localize and he died.

Autopsy showed two perforated ulcers of the upper portion of the ileum. In all other respects the intra-abdominal picture was similar to that observed in the previous cases. This is the only case in which a demonstrable ulcer of the intestine developed.

The histories in the 2 cases in which I operated recently are typical of the group and are presented briefly.

REPORT OF TWO CASES

CASE 1.—Radical orchietomy (left testis) was done overseas on Sept 7, 1945. The pathologic diagnosis was seminoma. The patient was transferred to Walter Reed General Hospital for radiation therapy. During the period from Oct 27 to Dec 20, 1945 he received 5,200 r to each of five portals: left suprapubic, umbilical, epigastric, lumbodorsal and lower dorsal. The total dose of high voltage radiation given in the region of the stomach totaled 10,400 r, administered through the epigastric and lower dorsal portals.

Mild radiation sickness developed. A roentgenographic series of the gastrointestinal tract, taken Jan 30, 1946, was reported as showing "no organic lesions of the esophagus, stomach or duodenum."

On March 11, about three months after irradiation, he experienced moderate epigastric discomfort, which was relieved by food or milk. Fluoroscopic examination on March 13 was reported as follows: "The esophagus is normal, the mucous membrane of the stomach is greatly hypertrophied. The antrum shows spastic contraction. The duodenal cap fills normally. The picture suggests the effects of irradiation."

Epigastric distress increased. Fluoroscopic examination on April 20 was reported as follows: "The stomach shows narrowing and spasm toward the antrum. The pyloric sphincter remains patent, but flow through the sphincter is slow, with decreased peristalsis. Ulceration is suspected." Gastric analysis showed slight elevation of free hydrochloric acid.

On May 15 the patient was reported to have been vomiting small amounts of blood several times a day. Epigastric distress was less acute. Fluoroscopic examination on May 24 was reported as follows: "The rugae of the stomach are hypertrophied, the antral portion is narrow with distorted, smoothed-out rugae. Peristaltic waves are decreased over the antrum. The impression is that of radiation gastritis with ulceration."

There was further frequent bleeding, with vomiting of small amounts of blood, discomfort was less acute. On June 27 subtotal gastric resection was done,

with the Hoffmeister type of anastomosis (fig 1) Recovery was uneventful Repeated physical and fluoroscopic studies showed no evidence of metastasis

CASE 2—Radical orchectomy (left testis) was done on Oct. 9, 1945, no metastasis was seen The pathologic diagnosis was teratoma of the testis, mixed type

Radiation therapy was administered from Nov 27 to Jan 5, 1946, 4,800 r being given to each of the five usual portals A total dose of 9,600 r was delivered in the region of the stomach

Moderate radiation sickness developed By the end of March, three months after irradiation, the patient complained of occasional epigastric pain The usual

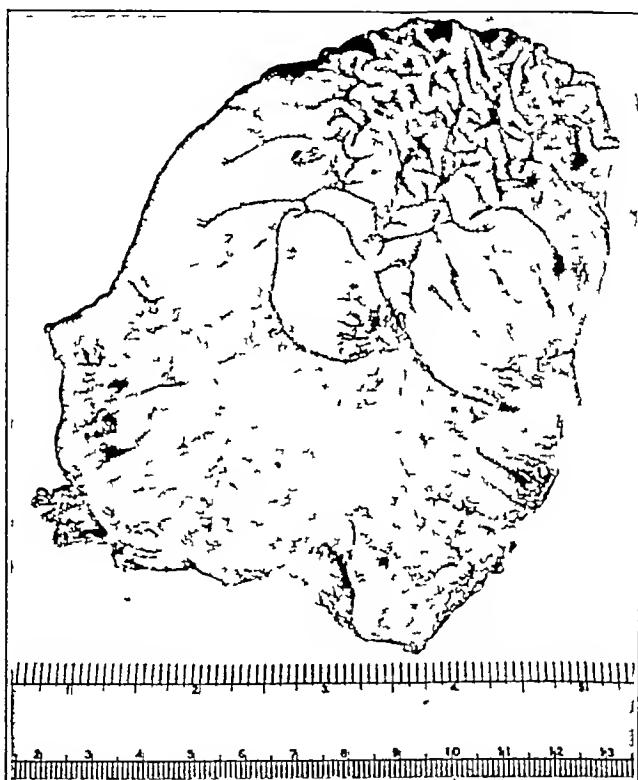


Fig 1 (case 1)—Interior of the stomach, showing hypertrophied rugae in the cardiac portion and absence of rugae in the irradiated portion, with petechial mucosal hemorrhages and increasing edema near the pylorus A portion of the ulcer appears at this point

regimen for control of ulcer was instituted, with control of pain By mid-April the patient occasionally vomited small amounts of blood and occasionally had tarry stools At times there was considerable loss of blood through the intestinal tract The hemorrhage was controlled by medical means, and for a time the patient was practically asymptomatic On August 11 the ulcer perforated and at once encapsulated posterior to the stomach (fig 2) An elective subtotal gastric resection was accomplished on August 15, with the Polva type of anastomosis, recovery was complete

Gastric analysis during this period showed no free hydrochloric acid on March 2, slight increase in free acid on March 16 and a subnormal amount of free acid on August 14.

Fluoroscopic findings were reported as follows:

January 24 No evidence of organic lesion

February 16 Hypertrophied rugae, central bulge on the greater curvature, simulating an ulcer crater

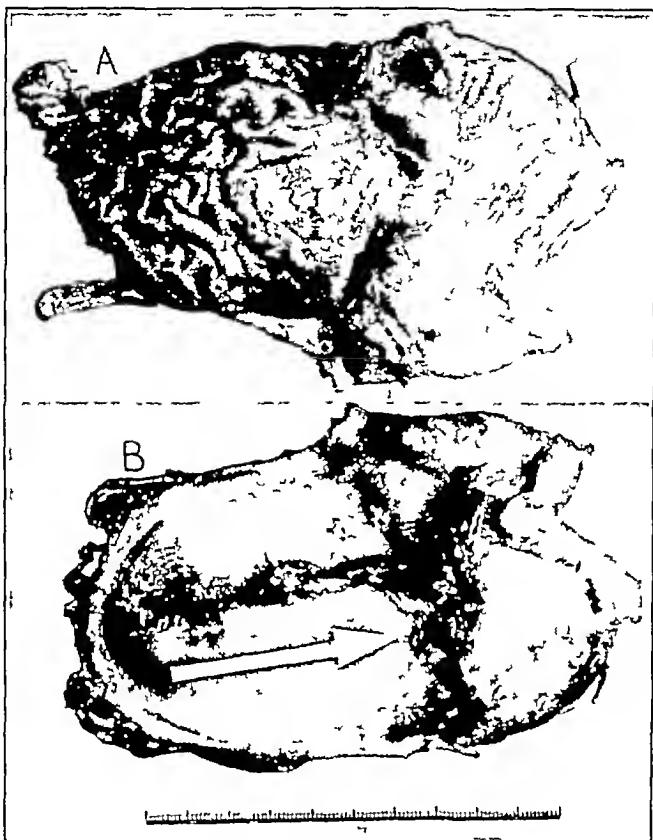


Fig 2 (case 2).—*A*, interior of the stomach presenting the same characteristic appearance as that of the stomach in figure 1. The perforated ulcer is visible near the center of the specimen. *B*, stomach opened along the greater curvature. The arrow points to the perforation near the edematous pylorus.

March 30 Increased changes, no peristalsis in the antrum, definite evidence of ulcer

April 29 Persistent barium-filled niche in the antrum near the greater curvature

May 8 Antrum fixed, small and canalized, ulcer, 3 by 3 cm, on the greater curvature in the proximal half of the antrum, pylorus widely opened and fixed

SUMMARY

Conclusions cannot be drawn from this small series of cases. However, certain observations seem constant. Unless these observations

are correlated, however, an increase in postradiation ulcer may be expected as additional tumor centers place in operation high voltage radiation therapy.

Two hundred and fifty-six patients received massive high voltage roentgen therapy for malignant growths of the testis at Walter Reed General Hospital. The apparent incidence of clinical cure of the malignant process was high—80 per cent for seminoma and 50 per cent for teratocarcinoma.

Certain unusual gastrointestinal complications occasionally arise during the course of treatment. One-half the patients treated experienced atypical epigastric distress from two to three months after irradiation. In 35 of these patients proved gastric ulcer developed in a previously normal stomach. However, if radiation therapy will apparently cure certain malignant growths of the testis, the subsequent development of gastrointestinal complications of moderate severity is relatively immaterial.

All the patients in whom radiation ulcer developed had a dose of radiation to the region of the stomach exceeding 5,000 r. Some patients, however, had radiation doses to the region of the stomach far exceeding 5,000 r with no ill effects. Thus, there appears to be an individual tumor sensitivity to radiation, as well as a personal sensitivity to the effects of radiation.

On the basis of these few cases, it is believed that the roentgenologist may predict the formation of an ulcer. Fluoroscopic examination has shown retardation and, finally, apparent absence of peristalsis in the antrum of the stomach in certain patients who have received heavy radiation to the retroperitoneal nodes. Later, in some of these patients a proved ulcer developed.

The symptoms were atypical of gastric ulcer. The effect of radiation on the gastrointestinal tract presents an unusual pathologic picture, but the lesion is by no means inoperable, as has been reported.

Further investigation is required to determine the exact causative factors in formation of the ulcer. There appears, however, to be an intimate relationship between the total radiation delivered to the region of the normal stomach and the development of this atypical gastric ulcer.

There have been 8 reported deaths with autopsy—6 in civilian hospitals and 2 in Walter Reed General Hospital. Subtotal gastric resection for radiation ulcer has been reported in 8 cases—2 in civilian hospitals, with postoperative death in both cases, and 6 in Walter Reed General Hospital, with postoperative death in 1 case, no improvement in 1 case and apparent clinical cure in 4 cases.

Walter Reed General Hospital, Washington 12, D C

ANATOMIC DISTRIBUTION OF THE VAGUS NERVES AT LOWER END OF THE ESOPHAGUS

Relation to Gastric Neurectomy for Ulcer

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SINCE Brodie's¹ first report, in 1814, on denervation of the stomach, an extensive and confusing literature has appeared. In many instances, in the literature reviewed on this subject the early and late effects of denervation have been confused and the results of section of the gastric nerves of man have been compared indiscriminately with those obtained on lower animals. Different workers have employed operations of different extent, and many investigators, too, have employed gastric neurectomy in the experimental production of peptic ulcer.² That there is no agreement on even the structure of these nerves, let alone their function, is reflected in recent reports, in one of which the author³ concluded that the vagus nerve is composed of nothing but sympathetic fibers whereas in another⁴ the authors denied the presence of any sympathetic fibers. In the present study we are concerned chiefly with clarification of the distribution of the gastric nerves immediately above and below the esophageal hiatus of the diaphragm.

Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec 6, 1946

1 Brodie, B C, cited by Hartzell¹⁰

2 Beaver, M G, and Mann, F C The Production of Peptic Ulcer After Section of the Gastric Nerve, Ann Surg 94 1116-1118 (Dec.) 1931

3 Kiss, F The Relation Between Vagus and Sympathetic in the Vertebrates, J Anat 66 153-156 (Oct.) 1931

4 McSwiney, B A, and Spurrell, W R The Gastric Fibres of the Vagus Nerve, J Physiol 77 447-458 (March 15) 1933

At the meeting of the Central Surgical Association in February 1946, one of us (W W) discussed with Dr Edwin Miller,⁵ of Chicago, the problem of division of the vagus nerves in treatment of ulcers of the stomach and duodenum. Dr Miller said that in dissection of approximately 30 vagus nerves he had been astonished to observe great variation of distribution of this nerve in the vicinity of the diaphragm. He expressed the belief that the patterns of distribution should be studied to determine whether all of the gastric branches of the vagus (or gastric) nerves could be removed successfully by transabdominal approach. He suggested that we at the Mayo Clinic might collaborate in such a study. The possibility of carrying out the study was discussed with Dr J W Kernohan, of the Section on Pathologic Anatomy, and the work was begun with a survey of the literature, only a little of which will be reviewed here, and the dissection of the vagus nerves at autopsy in more than 100 cases.

Anatomic consideration of the nerves revealed a varied pattern in their course from the pulmonary plexus to the stomach and a remarkably constant course and distribution after the nerves reached the stomach. In dissection we concentrated on the region just above the stomach in order to determine whether the thoracic or the abdominal approach to the lower part of the esophagus was better.

ANATOMIC VARIATIONS OF THE GASTRIC NERVES

Our observations were made on 56 men, 44 women and 11 children. In general, the gastric nerves arose from the esophageal plexus at about the level of the bifurcation of the trachea. The right and left nerves coursed caudad and usually terminated on the stomach. Certain variations, however, led us to separate our cases into four groups.

According to Cunningham,⁶ the vagus nerves as they pass from the esophageal plexus downward on the front and back of the esophagus through the opening in the diaphragm are termed "anterior" and "posterior" gastric nerves, respectively. In our investigations, the right nerve was not always posterior nor the left nerve always anterior to the esophagus as it passed through the esophageal hiatus and we proposed the terms "right gastric nerve" and "left gastric nerve." Since any surgical procedure which would excise a section of a nerve is a neurectomy, the term "gastric neurectomy" is used for resection of the gastric nerves.

In 92 of our cases among adults the gastric nerves took origin from the esophageal plexus. In 85 of these cases this occurred on the anterior

⁵ Miller, E. Personal communication to the authors.

⁶ Cunningham, D T. *Text-Book of Anatomy*, New York: Oxford University Press, 1943.

wall of the esophagus behind the bifurcation of the trachea and behind the main bronchi. In 7 cases it occurred on the lower part of the esophagus. As the gastric nerves coursed caudad, many intercommunicating branches were observed between the right and the left

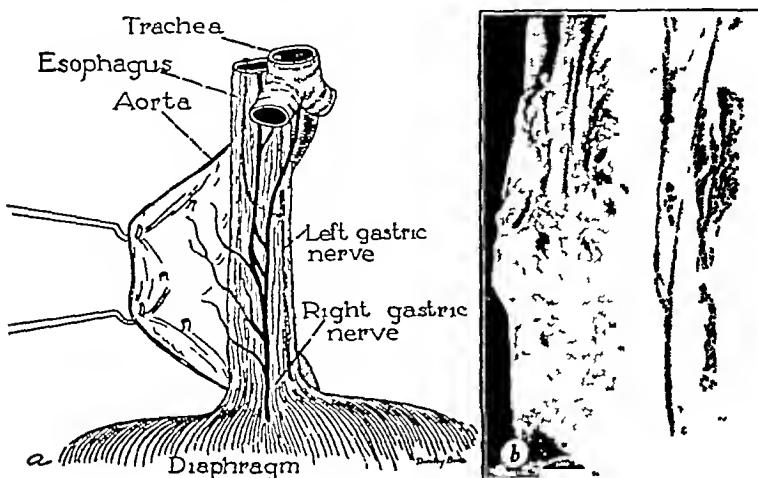


Fig 1a and b.—Formation of right gastric nerves from branches of the pulmonary plexus behind the trachea and the sympathetic branches posteriorly (group 1)

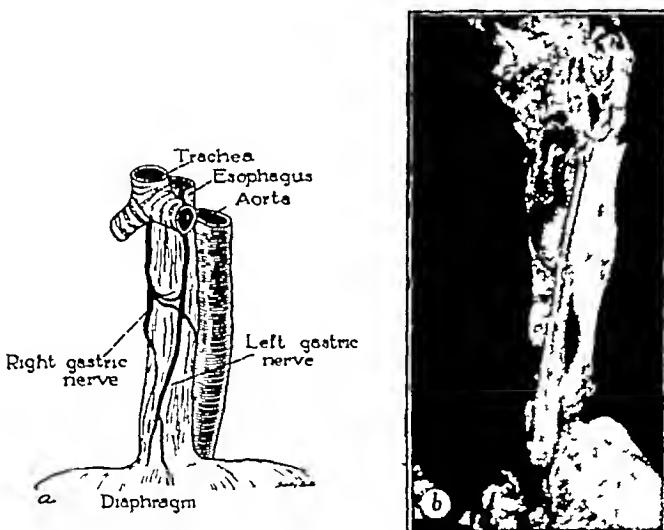


Fig 2a and b.—Formation of gastric nerves, demonstrating the absence of intercommunicating branches between the esophageal hiatus and a level 6 cm above the diaphragm (group 2)

trunks. Additional fibers which joined the gastric nerves were small fibers that coursed anteriorly and inferiorly over the vertebral column and the aorta. Communicating branches were sometimes seen to enter the musculature of the esophagus and either lose their identity or

re-emerge onto the surface of the esophagus at some more caudad position. By the time the nerve trunks and branches had reached the esophageal hiatus two relatively large trunks were formed. These trunks passed through the esophageal hiatus, below which their course was remarkably constant.

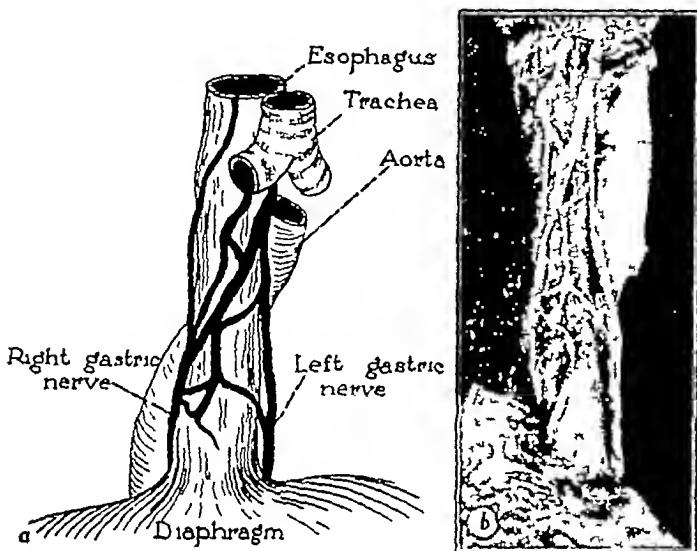


Fig 3a and b—Formation of gastric nerves from the esophageal plexus (group 3)

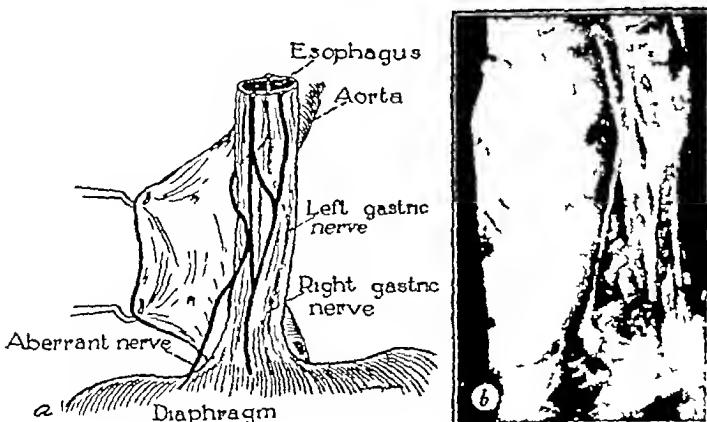


Fig 4a and b—Right gastric nerve with aberrant nerve coursing laterally into the thorax (group 4)

The 92 cases constitute three of our four groups. In the first group all the branches between the gastric nerves and from more remote regions joined in common trunks, one on the right and one on the left side of the esophagus, somewhere between the esophageal hiatus and 6 cm above the diaphragm (fig 1a and b). There were

64 such cases. In the second group long, discrete trunks were present without any addition to their fibers or any communicating branches for a distance of 6 cm above the diaphragm (fig 2a and b). There were 21 such cases. In the third group the many intercommunicating branches between the main trunks of the gastric nerves formed a plexus over a major portion of the surface of the esophagus. The branches ultimately united and formed two main trunks at the esophageal

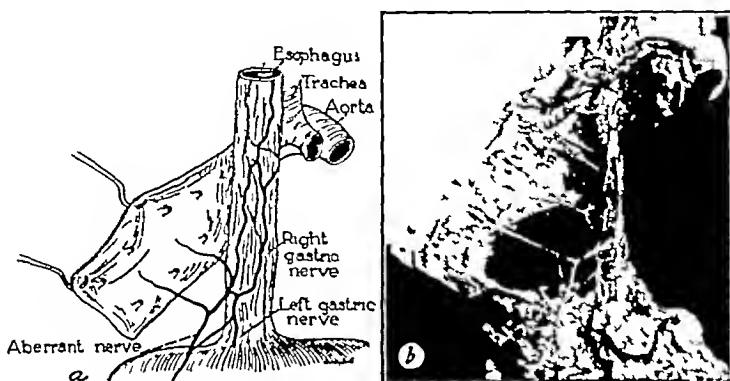


Fig 5a and b.—Another example of distribution of the gastric nerves in group 4

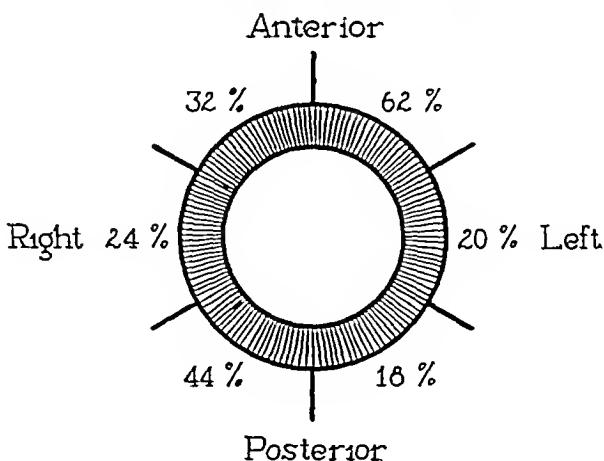


Fig 6.—Relative position of the right and left gastric nerves about the esophagus at the level of the esophageal hiatus

hiatus (fig 3a and b). There were 7 such cases. The remaining 8 cases made up the fourth group. In this group the nerves did not have a consistent or uniform course or pattern. In some cases well formed trunks were present, but somewhere near the diaphragm a well defined branch would leave the main trunk and course laterally in the thorax and lose its identity before leaving the thorax (fig 4a and b). In other cases the numerous branches of the esophageal plexus

failed to form into common trunks on one or both sides of the esophagus (fig 5 *a* and *b*) In such cases the multiple small fibers followed their course along the esophagus, some passed through the esophageal hiatus, and some ran laterally in the thorax. In such cases as these, we were never certain of the distribution of every fiber of the right and left gastric nerves. Hence, in cases of this type section of all the gastric nerves might prove difficult for the surgeon.

As the trunks passed through the esophageal hiatus, we noted the relative position of the right and the left trunk about the esophagus (fig 6) The course of the nerves was strikingly constant below the esophageal hiatus. The right gastric nerve, the larger in 54 cases, coursed posteriorly and to the left. After running about 3 to 5 cm, this nerve divided into numerous branches. One of these branches followed the lesser curvature of the stomach as far as the incisura, and another large branch followed the left gastric artery. We did not carry our routine dissections beyond the division of the right gastric nerve into these branches.

The course of the left nerve in the abdomen was short. As the nerve came to lie on the anterior surface of the stomach it divided into numerous small branches, which lost their identity in the serosa and the musculature of the stomach. Occasionally a small communicating branch between the right and the left gastric nerve could be identified at the esophageal hiatus.

CLINICAL STUDIES

The clinical application of these anatomic studies to the treatment of peptic ulcer has been made in 66 cases⁷ at the Mayo Clinic (tables 1 to 8) and has led one of us (W W) to believe that the best approach to the gastric nerves is by an incision in the upper part of the abdomen. This approach permits exploration of the contents of the abdomen, examination of the ulcer and its removal if it is a gastric ulcer and is suspected of being malignant. Also, this approach permits some type of drainage of the stomach if an obstructive duodenal ulcer is present or if a duodenal ulcer is present that is likely to become obstructive with the occurrence of gastric atony after gastric neurectomy. Patients with ulcers of the types just mentioned usually have failed to respond to many attempts at nonsurgical (medical) treatment. The abdominal approach is also useful in cases in which a gastrojejunal ulcer has followed gastroenterostomy, for not infrequently repeated ulceration at the stoma has resulted in obstruction and reactivation of the duodenal ulcer. In such cases, removal of the gastrojejunal

⁷ Dr Walters' assistants, Drs Fitzgibbons, Watts, McVicker, Brownson, Lowe and Lyman, assisted in reviewing and abstracting the case records and in tabulating the results.

ulcer and disconnection of the gastroenteroanastomosis are advisable in addition to gastric neurectomy. If obstruction of the duodenum has resulted from reactivation of the duodenal ulcer or from its healing after the gastroenterostomy, pyloroplasty also is indicated. In a case in which an ulcer recurred after gastric resection performed elsewhere, perforation of the anastomotic ulcer into the colon was impending at the time of operation. In this case we felt that a more extensive

TABLE 1.—*Clinical Data on Authors' Ten Cases in Which Gastric Neurectomy (Vagotomy) Only Was Performed*

Case	Lesion	Total and Free Acids (Degrees), Gastric Contents, Cc		Minimal Blood Sugar, Mg per 100 Cc	Curve for Insulin Test	Roentgenologic Findings	Comment and Results
		Before Opera- tion	After Opera- tion				
1	Gastro- jejunal ulcer	28/12 45 cc.	40/0 40 cc	20	Flat		Good relief
2	Gastro- jejunal ulcer	82/16 60 cc.	12/0 75 cc. (night)	33	Flat	Moderate delay in emptying	Excellent relief
3	Gastric ulcer		26/0 60 cc. (night)	53	Flat	Atonic stomach, considerable secre- tion	Good relief early, but per- sistence of re- tained secre- tions
4	Gastric ulcer		20/0 600 cc. (night)	22	Downward	Normal motility	Good relief
5	Bleeding duodenal ulcer		10/0				Retention of 900 to 2,300 cc. 4 to 9 days af- ter operation
6	Duodenal ulcer	64/54 75 cc	6/0 141 cc. (night)	28	Downward		Dramatic relief
7	Duodenal ulcer	46/24 150 cc	40/28 100 cc. (incorrect)	7	Upward		Good relief*
8	Duodenal ulcer	56/46 115 cc.	14/0 10 cc	76	Upward	Normal	Good relief
9	Duodenal ulcer	60/40	20/0 50 cc			Duodenal ulcer with no crater normal motility	Good relief
10	Duodenal ulcer	64/52 130 cc	34/20- 450 cc (night)	28	Downward	Considerable secre- tion in stomach	Good relief

gastric resection was indicated, with removal of the anastomotic ulcer, even though gastric neurectomy was done also.

It is easy to understand, therefore, why gastric neurectomy was done without any additional surgical procedure on the stomach in only 10 of the 33 cases in which one of us (W.W.) performed gastric neurectomy and in 13 of 33 cases in which operation was performed by other surgeons. Since gastroenterostomy and partial gastrectomy without gastric neurectomy in the treatment of patients with peptic ulceration have been followed by relief of pain, decrease of night secre-

TABLE 2.—Clinical Data in Cases in Which Gastric Neurectomy and Gastroenterostomy Were Performed Simultaneously

Case	Type of Gastroenterostomy	Lesion	Total and Free Acids (Degrees), Gastric Contents, Cc.		Minimal Blood Sugar, Mg per 100 Cc	Curve of Insulin Test	Roentgenologic Findings	Comment and Results
			Before Operation	After Operation				
11	Posterior	Duodenal ulcer with obstruction	70/50, 375 cc	20/16, 30 cc	32	Downward		Excellent relief
12	Posterior	Perforating duodenal ulcer	98/58, 150 cc					Good relief
13	Posterior	Hemorrhagic duodenal ulcer with obstruction	78/50, 275 cc	10/0, 370 cc			Normal	Good relief
14	Posterior	Perforating duodenal ulcer with obstruction	70/54	10/0, 100 cc			Good relief	Good relief
15	Posterior	Perforating duodenal ulcer with obstruction	80/68	10/0, 100 cc			Normal	Good relief
16	Posterior	Perforating duodenal ulcer with obstruction	80/50	40/0, 60 cc (night)	32	Downward	Gastropasm	Good relief
17	Posterior	Duodenal ulcer with obstruction	40/30, 17 cc.	10/0, 600 cc (night)	0	Flint	Normal	Good relief
18	Posterior	Duodenal ulcer with obstruction	78/54, 200 cc	8/6, 13 cc	22	Flint	Dilatation with retained secretions	Slight fullness with food, good relief of ileus, exploration, retention of 800 cc of secretion
19	Posterior	Puncturing, bleeding duodenal ulcer with obstruction			34/22		Rapid emptying of stomach, delay in small bowel	Retention of 2,000 cc 4 to 14 days after operation, recurrence, slight fullness with pain and vomiting
20	Posterior	Duodenal ulcer with obstruction	68/55, 100 cc	22/16, 100 cc			Dilated duodenum gastroenterostomy free but high Edema in mesentomosis	Obstruction for 14 days, good relief
21	Posterior	Duodenal ulcer	32/18, 500 cc	14/0, 300 cc (night)	40	Flint		
22	Anterior enteroanterior tomosis	Duodenal ulcer with obstruction	60/50, 175 cc	40/0				
23	Interior	Duodenal ulcer with obstruction	60/40	61/54, 200 cc			Considerable retention	Retention of 900 cc 4 days after operation, poor relief

tion, reduction of gastric acidity and relief of gastrospasm, the difficulties of determining the effect of an associated gastric neurectomy are evident, both from the subjective and the objective standpoint. Conse-

TABLE 3—*Clinical Data in Cases of Gastric Neurectomy with Simultaneous Operation on Stomach*

Case	Lesion	Total and Free Acids (Degrees), Gastric Contents, Cc.			Minimal Blood Sugar, Mg per 100 Cc.	Curve Test	Roentgenologic Findings	Comment and Results
		Before Opera-tion	After Opera-tion	Blood				
24	Gastrojejunul ulcer	Gastroenteroanastomosis 20/6 125 cc (night)	30	Curve Flat	Disconnected,	Ulcer Excised	Slight deformity of duodenal cap, jejunitis, in proximal part of jejunum	Excellent relief
25	Gastrojejunul ulcer	58/42 200 cc (night)	10/0 80 cc (night)	43	Downward			Excellent relief
26	Malfunctioning stoma with obstruction	Gastroenteroanastomosis 72/60 55 cc. (night)	84/50 160 cc. (night)	30	Downward	Disconnected, Ulcer Excised, Heineke-Mikulicz Pyloroplasty	Gastric pyloric spasm	Good relief
27	Gastrojejunul ulcer	Gastroenteroanastomosis 54/40 200 cc (night)	60/36 800 cc (night)	20	Downward	Disconnected, Ulcer Excised, Flinney Pyloroplasty	Duodenum deformed by previous ulcer, stomach slightly atonic	Early retention, gradual decrease in 4 to 6 days, good relief
28	Gastrojejunul ulcer	Gastroenteroanastomosis 24/10 104 cc	6/0 50 cc			Disconnected, Anterior Polya Resection	Free anastomosis, bowel normal	Good relief
29	Duodenal ulcer	Duodenal Ulcer Excised, Gastroduodenostomy 66/48 200 cc. (night)	22/0 325 cc. (night)	86	Flat			Good relief
30	Gastric ulcer	Biopsy of Ulcer and Cautery 12/0 50 cc. (night)						Good relief
31	Gastric ulcer and duodenal ulcer	Transthoracic Exploratory Gastroscopy, Biopsy of Gastric Ulcer, Gastric Closure 64/52 11/11/46 40/28 250 cc	22/0 800 cc (night)	45	Downward		Recurrence of ulcers, but essentially normal emptying of stomach	Moderate early retention poor result
32	Gastric ulcer, healed duodenal ulcer	Gastric Ulcer Explored 50/84 180 cc.	28/0 200 cc	45	Upward then downward	Normal		Good relief
33	Gastritis	Exploratory Gastroscopy Only 54/42 880 cc	8/0 40 cc.	78	Upward	Normal		Good relief

quently, patients on whom no simultaneous operation is performed on the stomach are best to study in order to evaluate the results of gastric neurectomy.

TABLE 4—*Data in Significant Cases of Gastric Neurectomy (Vagotomy) Performed by Other Surgeons*

Case Number	Transthoracic Approach for	Free and Total Acids (Degrees), Gastric Contents, Cc		Minimal Blood Sugar, Mg per 100 Cc.	Curve of Insulin Test	Roentgenologic Findings	Comment and Results
		Before Opera- tion	After Opera- tion				
34	Gastroje- junal ulcer	64/46 185 cc.	20/0 210 cc				Excellent relief
35	Gastroje- junal ulcer	62/59 100 cc.	14/0 90 cc	37	Flat	No ulcer seen Temporary delay in jejunum	Good relief
36	Gastroje- junal ulcer	36/26 105 cc	18/0 80 cc			Free anastomosis, no gastrojejunal ulcer	Good relief
37	Gastroje- junal ulcer	1944 112/100 150 cc 1945 40/20 100 cc.	12/0 50 cc				No pain, slight tendency to diarrhea
38	Duodenal ulcer	60/46 130 cc.	50/28 200 cc	38	Down- ward		Good relief
39	Duodenal ulcer	78/68 100 cc.	5/31/46 26/12 320 cc. 6/1/46 62/50 150 cc				Early retention, good relief consider- able eructation
40	Duodenal ul- cer (abdom- inal approach)	74/56 150 cc.	40/20 40 cc				Early retention intermittent vomit- ing and diarrhea

TABLE 5—*All Cases of Gastric Neurectomy Performed at Mayo Clinic
Up to Nov 1, 1946*

Type of Operation	Total No of Cases	Duodenal Ulcer	Gastro- jejunal Ulcer	Gastric Ulcer	Gastritis
Gastric neurectomy only	28	11	10	2	0
Gastric neurectomy with gastroenterostomy	29	29	0	0	0
Gastric neurectomy with excision of ulcer	14	4*	7†	5*	1
Total number of cases	66	44*	17†	5*	1

* Both duodenal and gastric ulcer in 1 case

† Gastrojejunocolic fistulas in 2 cases

TABLE 6—*Authors' Cases of Gastric Neurectomy Performed Up to No. 1, 1946*

Type of Operation	Total No of Cases	Duodenal Ulcer	Gastro- jejunal Ulcer	Gastric Ulcer	Gastritis
Gastric neurectomy only	10	6	2	2	0
Gastric neurectomy with gastroenterostomy	13	18	0	0	0
Gastric neurectomy with excision of ulcer	10	2*	5	5*	1
Total number of cases	33	21*	7	5*	1

* Both duodenal and gastric ulcer in 1 case

RESULTS OF GASTRIC NEURECTOMY

The results in the 10 cases in which one of us (W W) performed gastric neurectomy without other surgical procedures on the stomach were satisfactory in so far as they were measured by relief of pain, reduction of gastric acidity and gastric secretion (table 1). One patient

TABLE 7.—Complications Following Gastric Neurectomy in Thirty-Three Cases (Other Surgeons)

Type of Operation	Total No of Cases	Retention		Cases	Results Type
		Early Clinical	Roentgenologic		
Gastric neurectomy only	18	2	1	1	Early pleural effusion, epigastric distress
				1	Recurrent abdominal pain
				1	Tendency to slight diarrhea
				1	Early retention, followed by intermittent emesis and diarrhea
				1	Considerable belching
				1	Death on fourth postoperative day probably pulmonary embolus
Gastric neurectomy with gastroenterostomy	16	3	0	1	Death on fourteenth postoperative day from perforated duodenal ulcer and subdiaphragmatic abscess
Gastric neurectomy with excision of jejunocolic fistulas	2	0	0	1	Death of unknown cause three months after operation
Excision of duodenal ulcer	2	0	0	1	Recurrent pain at night

TABLE 8.—Relation of Free Gastric Acidity to Type of Gastric Operation (Authors' Cases)

Type of Operation	Acidity Before Operation			Acidity After Operation		
	Total No of Cases	Determinations Made		Mean Value Units	Determinations Made	
		Cases	Mean Value Units		Cases	Mean Value Units
Gastric neurectomy only	10	7	30.0	10	28	
Gastric neurectomy and gastroenterostomy	13	12	53.2	11	12.2	
Gastric neurectomy and excision						
Gastrojejunular ulcer	5	4	38.0	5	18.8	
Gastric ulcer	3	3	20.0	3	0	
Duodenal ulcer	1	1	48.0	1	0	
Gastritis	1	1	42.0	1	0	
All cases	10	9	33.6	10	9.4	
Grand total	83	28	41.1	31	8.8	

(case 3, table 1) who was operated on for a gastric ulcer complained of a sensation of fulness after eating small amounts of food. At the time of this report, several weeks after operation, he continues to have a dilated stomach with pylorospasm, retention of considerable gastric secretion and hypomotility of the intestine. There was so much fluid in the stomach that the roentgenologist could not see whether the ulcer had healed. In 8 of these 10 patients relative achlorhydria

followed the operation. Relative achlorhydria also developed after operation in 6 of 11 cases of duodenal ulcer in which simultaneous gastroenterostomy and gastric neurectomy were performed and tests of acidity were made (table 2). This incidence of achlorhydria contrasts favorably with an incidence of 12 per cent in a series of cases of gastroenterostomy which I reported several years ago.⁶ In 4 of the 5 remaining cases gastric acidity was reduced. The insulin test, however, was not carried out to confirm the completeness of neurectomy in the fifth case, and the patient was only partially relieved of his symptoms. In 1 of our 33 cases (tables 1, 2 and 3) a large gastric ulcer recurred, and in 1 of 33 cases in which the operation was performed in other services at the clinic a duodenal ulcer perforated, with development of a subdiaphragmatic abscess, and death occurred on the fourteenth day after gastric neurectomy and gastroenterostomy. Retention of gastric secretion and severe hypoproteinemia were also present. In this case, also, the insulin test to confirm the completeness of the neurectomy was not made, and postmortem examination of the gastric nerves to ascertain the completeness of the neurectomy, unfortunately, was omitted.

Postoperative disturbances of gastrointestinal motility were troublesome in 6 of our 23 cases (tables 2 and 3) in which additional operations on the stomach were performed simultaneously. Characteristic of 3 of these 6 cases was intermittent paroxysmal distention of the abdomen, which was relieved by injections of neostigmine methylsulfate. In 1 of the 3 cases (case 19, table 2) distention appeared on the fifth day after operation and increased during the next two days. Roentgenologic examination of the abdomen revealed what seemed to be obstruction of the small intestine, and exploratory operation revealed ileus, the small intestine was filled with fluid and air or gas, and there was approximately 800 cc of sterile, straw-colored fluid within the peritoneal cavity. Continuous gastric suction with an indwelling nasal suction tube relieved the distention in this case, and normal intestinal motility returned. Two of the 6 patients had clinical symptoms of gastric retention and required intermittent drainage with a gastric tube from the fourth to the eleventh day after operation. An additional patient (case 22, table 2) had gastric retention for twenty-six days, which required jejunomejunostomy for relief. Reduction in gastric acidity and night secretion in both groups of cases are shown in tables 1 to 4. In many cases in each group postoperative studies of gastric motility and roentgenoscopic and roentgenographic examinations were made after the patient left the hospital on approximately the

⁶ Walters, W. Gastric Acidity Following Operations for Gastric and Duodenal Ulcer. Its Effect on the Question of Partial Gastrectomy, *Ann. Surg.* **104**: 585-593 (Oct.) 1936.

fourteenth to the twentieth postoperative day. In 10 of the 33 cases in which one of us (W.W.) performed gastric neurectomy temporary disturbances of gastric motility with retention of gastric secretion occurred. In 1 case, as mentioned previously, these symptoms persisted for several weeks (case 3, table 1). In 2 of our colleagues' 13 cases in which gastric neurectomy alone was performed intermittent diarrhea has occurred since the operation.

Insulin Test.—On evaluating results of gastric neurectomy, it is, of course, important to determine that all the gastric (vagus) nerves have been divided. Unfortunately, the insulin test, described by Hollander⁹ to determine whether complete division of the gastric nerves has been accomplished, involves some risk and must be made only under the constant supervision of a physician who has dextrose available for immediate administration if symptoms of hypoglycemic convulsions manifest themselves. The test itself consists of injection of 10 to 30 units of insulin, in order to reduce the patient's blood sugar to 40 mg or less per hundred cubic centimeters. If branches of the gastric nerves are intact, an increase in the gastric secretion occurs in from forty to fifty minutes after injection of the insulin.

COMMENT

Seventeen years ago, in the Division of Experimental Surgery and Pathology of the Mayo Foundation, studies were made by Hartzell¹⁰ and Vanzant¹¹ on the effects of intrathoracic and abdominal section of the vagus nerves in dogs. Hartzell first studied 8 animals, 6 after intrathoracic vagotomy and 2 after abdominal vagotomy. Immediate observations showed total abolition of psychic secretion (cephalic phase) with pronounced and constant reduction of free hydrochloric acid and total acidity and an increase in the hydrogen ion concentration. Vanzant studied 4 of the same dogs two and a half years later and found that the dogs of the original group had an increase in the amount of total and free acid after five to six months. Eventually, the curves of free and total acid approached normal. In 1 dog the acidity was slightly increased above normal levels, and in 3 dogs there was moderate, but not complete, restoration to the normal level of acidity. This return of gastric acidity also occurred clinically in 1 of the patients operated on at the clinic. At first, a relative achlorhydria was present after opera-

9 Hollander, F., in discussion on papers by Drs. Berk and Frediani, Ivy and Dragstedt, and others, *Gastroenterology* 3: 466-467 (Dec.) 1944.

10 Hartzell, J. B. The Effect of Section of the Vagus Nerve on Gastric Acidity, *Am J Physiol* 91: 161-171 (Dec.) 1929.

11 Vanzant, F. R. Late Effects of Section of the Vagus Nerves on Gastric Acidity, *Am J Physiol* 99: 375-378 (Jan.) 1932.

tion With a return of gastric acidity to the preoperative level symptoms of ulcer recurred Unfortunately, the insulin test was not made, so we do not know whether all the gastric nerves were resected

Effects on motility were observed to be inconstant in a study on 10 dogs made by Vanzant¹² Early studies showed that 4 dogs had delayed emptying of the stomach, 2 dogs had gastrointestinal hypermotility with a tendency to diarrhea and emesis and 3 dogs had no change in the emptying time of the stomach Later, after operation, essentially normal gastrointestinal motility was observed in 7 dogs One dog had rapid emptying of the stomach, 1, a slight delay, and 1, pronounced delay No bad effects on the general health followed the operation on 6 dogs except for excessive salivation, which gradually decreased Two dogs vomited frequently after the operation Three dogs had increased appetite, in spite of which loss of weight was noted

Dragstedt¹³ treated his first patient with gastric neurectomy three and a half years ago, and Moore, Chapman and associates¹⁴ treated theirs more than two years ago Most of the more recent patients treated by these surgeons have so far been benefited The same is true in the series of cases reported by Grimson and his associates¹⁵ Yet, because of experimental evidence that changes in gastric acidity and motility after vagotomy may be only temporary, and because long experience with peptic ulcer makes us reserve our judgment concerning any operation until a large series of patients have been watched for many years, gastric neurectomy is being performed at the Mayo Clinic in selected cases of peptic ulcer only We think that the final report on this operation is not due for several years and that all reports now and for some years to come, should be considered interim reports

In the meantime the procedure can be used in certain types of cases 1 In cases of recurring ulcer after adequate gastric resection it seems justifiable to offer the patient the comparatively simple operation of gastric neurectomy on the chance that the ulcer will heal and he will obtain relief of symptoms 2 Possibly in certain cases of gastric ulcer in which excision of the ulcerating lesion and microscopic examination

12 Vanzant, F R The Late Restoration of Gastric Acidity After Thoracic Vagotomy in the Dog, unpublished data, footnote 11

13 Dragstedt, L R Vagotomy for Gastroduodenal Ulcer Ann Surg 122: 973-989 (Dec) 1945

14 Moore, F D Chapman W P Schulz, M D and Jones C M Trans Diaphragmatic Resection of the Vagus Nerves for Peptic Ulcer New England J Med 234: 241-251 (Feb 21) 1946

15 Grimson K S Taylor, H M, Trent I C Wilson D A and Hill H C The Effect of Transthoracic Vagotomy upon the Functions of the Stomach and upon the Early Clinical Course of Patients with Peptic Ulcer South Med J 39: 460-471 (June) 1946

are necessary to exclude the possibility that the ulcer is malignant, gastric neurectomy is advisable if the ulcer is benign. Yet in 1 of our cases troublesome symptoms referable to gastrointestinal motility, with gastric retention and pyloric obstruction, followed this procedure (case 3, table 1). 3 In certain cases of duodenal ulcer with hyperchlorhydria, gastric neurectomy with simultaneous gastroenterostomy to relieve the duodenal obstruction may be advisable. It will be interesting to see whether the incidence of recurring ulcer will be less than it is in cases in which gastroenterostomy only is performed. 4 In cases of chronic, nonobstructive duodenal ulcer, in which the cephalic phase of the hyperacidity seems to overshadow other factors and repeated courses of medical treatment have not given any relief, we believe that gastric neurectomy may be justified. Many of the patients with ulcer of this type are young and have high values for gastric acidity and active duodenal ulcers, and their behavior pattern suggests a prolonged and excessive nervous phase of gastric secretion.

SUMMARY AND CONCLUSIONS

There is considerable variation in the position, number, size and distribution of gastric nerves above the diaphragm. In 92 per cent of the adults studied, however, the gastric nerves, after piercing the diaphragm, appear as discrete trunks and are readily accessible for surgical removal by the transabdominal approach.

A study of 66 cases in which gastric neurectomy was done at the Mayo Clinic indicates that gastric acidity was reduced in most cases. Relief of symptoms of pain was not strikingly different from that obtained with rest in bed and established surgical procedures. Interpretation of the results of gastric neurectomy should be restricted to that group of cases in which the procedure is carried out without any simultaneous operation on the stomach. There were 23 such cases in our series.

A large gastric ulcer recurred in a case in which relative achlorhydria occurred immediately after operation. A few weeks after operation free hydrochloric acid was found to be present in the stomach. Symptoms of ulcer returned, and roentgenologic examination revealed recurrence of a large gastric ulcer which had been partially excised for microscopic examination at the time of transthoracic resection of the vagus nerve. Perforation of a duodenal ulcer with subdiaphragmatic abscess and death occurred fourteen days after operation in 1 of our colleagues' cases in which gastric neurectomy and gastroenterostomy were performed. In 2 other cases death occurred, in 1 on the fourth day after operation, from a suspected cerebral embolism, and in the other three months after operation at home, from coronary occlusion. In the

latter case a gastrojejunocolic fistula closed and gastric neurectomy was performed. In another case there was a return of gastric acidity with recurrence of symptoms of ulcer. Unfortunately, the insulin test was not made to determine the completeness of neurectomy.

In several cases disturbances of gastrointestinal motility occurred during the patient's stay in the hospital, in 1 case it has persisted for several weeks. In 1 case a secondary jejunoojejunostomy was required. In 1 case exploration was made for a suspected intestinal obstruction and ileus was observed, and in 2 cases intermittent diarrhea had persisted since operation.

Some method of testing to ascertain that all branches of the vagus nerves are divided is essential. The present method is the insulin test of Hollander, which must be carried out with great caution.

In view of the return of gastric acidity and gastrointestinal motility to normal or near normal in most experimental animals after an interval of two years, the possibility of the same result among human beings must be recognized. Hence, all reports on clinical results should be considered as interim reports until sufficient time elapses to determine whether a return of gastric acidity, motility and secretion to about preoperative levels occurs, with possibility of the formation of new ulcers.

To date, in the small series of 33 cases in which one of us (W.W.) employed gastric neurectomy, we have been impressed with the reduction of gastric acidity and the relief of pain which have followed complete gastric neurectomy, and we believe that the operation has merit, though the results may be temporary. The frequency of troublesome disturbances in gastrointestinal motility, the recurrence of ulceration in 1, and possibly in 2, cases, perforation of a duodenal ulcer after gastric neurectomy and gastroenterostomy in 1 of our colleagues' cases, the uncertainty of ultimate good results, the possibility of undesirable results not now evident, the necessity of performing additional procedures, such as gastroenterostomy, to relieve duodenal obstruction, the necessity of excision of ulcerating gastric lesions to exclude the presence of a malignant growth, and the death of 3 of the 66 patients indicate that we must continue to study the problem of the treatment of peptic ulcer, and not attempt to draw conclusions regarding the ultimate value of gastric neurectomy until more cases have been studied and a longer time has elapsed after operation.

Gastric neurectomy offers a method which gives great promise in the treatment of patients with recurring ulcer, especially after gastric resection and gastroenterostomy, and in the results to date in cases of this type gastric neurectomy has justified itself as a useful and important procedure. If it will prevent recurring ulceration after gastroenterostomy, it has further justified its value.

DISCUSSION ON PAPERS BY COLONEL HAMILTON AND DRS WALTERS, THOMPSON AND OTHERS

DR. ERWIN SCHMIDT, Madison, Wis This paper is of importance because of advances in radiation and atomic energy and the application of these forces to clinical use. Demonstrations such as this call attention in a dramatic way to the dangers associated with the application of these new potentia

Boyd's description of the effect of radiation energy has appealed to me, with its suggestion of certain clinical limitations On the pathologic cells there are caustic and lethal effects On the host, which furnishes the bed for the pathologic tissue, there is also an effect. The radiation energy acts on the pathologic cells, and also on the normal cells through which the radiation must pass This leads to destruction of tissue, both pathologic and normal Healing must take place through inflammation and fibrosis If enough energy is present to kill malignant cells, normal cells are killed also

Irradiation of the gastrointestinal tract has not been used except in cases in which the pathologic process is fixed Such a lesion often responds because some of the fixation is due to inflammation, which responds favorably to radiation This is particularly so in the sigmoid and the rectum Lesions in the gastrointestinal tract, except for carcinoma of the rectum, are usually not amenable to radiation In the rest of the tract, adequate radiation to the anaplastic cells would damage the bowel, as amply demonstrated by Colonel Hamilton Some malignant cells, such as those of lymphosarcoma, are more sensitive, and so a smaller dose causes the tumor to disappear and does not injure the bowel and the surrounding structures

My colleagues and I have had no experience, such as the author describes, with acute hemorrhage and perforation of radiation ulcer We have seen similar changes in the small bowel, such as those which occur in cases of carcinoma of the rectum in which heavy radiation has caught a loop of the intestine or in cases of inoperable tumor in which attempt has been made to control the anaplastic lesion with irradiation

The pathologic picture in the stomach as described by the author is similar to that familiar in reactions to roentgen radiation—the acute stage, in which gastroenteritis develops during the treatment, and the later stages, eventually leading to necrosis The experience of the plastic surgeon that excision of normal tissue is necessary to obtain healing demonstrates that the area affected is usually as wide as the area treated I do not feel that one must postulate a toxin or assume that the ulcer is similar to the ulcer of the duodenum described by Curling Local damage to tissue is sufficient, and the superficial necrosis following roentgen irradiation suggests local damage

DR. EDWIN M MILLER, Chicago I am sorry that Dr Dragstedt cannot be here to discuss Dr Walters' papers, for one has to look to the evidence presented by Dr Dragstedt, both experimentally and clinically, for the most reliable data on this subject to date It is well for the members of this society to take the proper attitude toward the problem of this operation and to realize that it is still in the formative stage (experimental stage, one might say) and that it is not fair to make too definite statements regarding the end results The pendulum will eventually swing back and only time will evaluate the procedure devised by Dr Dragstedt and determine its permanent merit

I had the opportunity to read Dr Walters' paper this morning and to go over his slides and drawings, it seems to me that his studies at the Mayo Clinic and the

statements in his paper are sound, reasonable and backed up by careful study. It is well for all of us who are interested in this problem to evaluate the evidence, without exaggeration, so that in due time we may accumulate data of permanent value.

My colleagues and I became interested in this problem a year or so ago, and we felt that before we could undertake operation on patients we must first investigate the problem from the anatomic standpoint. One would not think of performing extensive operations on the biliary tract, for instance, without having done considerable investigation of the anomalous structures which one might encounter in this region of the common duct, the cystic duct, the cystic artery and the right hepatic artery. The same might be said of anatomic studies on the neck, to determine the possible anomalous relations of the inferior thyroid artery, the parathyroid glands and the recurrent laryngeal nerve.

Therefore, we turned to the laboratory for this information and undertook a series of dissections. It soon became apparent that cadavers were not suitable, because in isolating delicate nerves, like the branches of the vagus, it was important to make the dissection on fresh bodies. Therefore, with the permission of the department of pathology of the University of Chicago, Dr. Carl Davis Jr. and I went to the autopsy room and made a series of studies of the vagus nerves from the pulmonary plexus down to the termination of the branches in the walls of the stomach. We concluded that there is considerable variation in the distribution of the vagus nerves; in fact, there is hardly any uniformity of distribution. A fair example of what one may encounter at operation may be seen on the first slide taken from Spalteholz' "Anatomy."

In section of the vagus nerves, it is important to divide not only the main trunks but also the several branches which may be accessory, therefore, the logical surgical approach is probably through the chest, where one has a fine exposure, a good view of the whole situation and a bloodless field in which to isolate the accessory branches. However, I may be wrong about that, for Dr. Walters has used the abdominal approach almost exclusively and Dr. Dragstedt of late, I think, also confines his approach to the subdiaphragmatic route. In spite of this, I still feel as I did originally, that the easier and the more accurate approach is through the chest.

The next slide shows the results in our first 11 dissections, I wish to point out that in only 2 instances was the situation comparable to what might be considered a normal distribution of the nerves. Some of the branches hugged the esophageal wall closely, while others were widely separated, and in 1 or 2 cases the small branches were so close to the mediastinal pleura on the right side that in picking them up one might easily tear the pleura at that point.

If one approaches from below the diaphragm and brings down the esophagus on the hooked finger, one may at first go in between the esophageal wall and the vagus trunks and, after a vain search, may have to look deeper for (especially) the right or posterior, trunk. Then, too, if one approaches from below, there may be a greater tendency to venous oozing in the field, for in some patients there is a considerable venous plexus in this area. But the approach from below the diaphragm obviously has its advantages. One can see the lesion in the duodenum or the stomach and can perform, if necessary, a gastroenterostomy or resection at the same time.

I should not attempt at this time to say anything about the end results of operation for our series of cases are relatively small both at the Prelinger in

Hospital and at the Veterans Hospital at Hines, Ill., and the time elapsed since our earliest operation has been only about one year. Certain things, however, stand out clearly in the postoperative picture. One is the feeling of "well-being" and freedom from distress that is observed soon after operation. In some cases there is a tendency toward cardiospasm and in others to pylorospasm, which may be troublesome for a time. In some cases there is a mild paralytic ileus, in others, a tendency toward diarrhea for several days. All these complications, however, are temporary and tend to pass away in a relatively short time. But the true answer to many of the questions will be found through a much longer study of the problem.

DR HARRY B ZIMMERMANN, St. Paul: In watching Dr Sanders operate on patients with gastric ulcer by resection of the vagus nerves, and in listening to the discussions, two things have struck me rather forcibly. One is that the surgeon does not operate for ulcer of the stomach unless the patient has had adequate medical management first. The second is that patients who have a vagotomy immediately experience a sense of well-being, not only are their symptoms of pain relieved but they feel fine. "I have not felt so well in years," said one of Dr Sanders' patients. Dr McNealy had the same experience.

Even if all the patients who have had vagotomies should have a recurrence of symptoms within five years, Dr Dragstedt has nevertheless accomplished a great deal. He has proved something definite. Many other surgeons have demonstrated this effect of nerve impulses. Dr Wangensteen, who advocates a considerable resection of the stomach, has proved to his own satisfaction that an exciting cause of the ulcer is excess of hydrochloric acid—not only an excess, but a continuance of the hydrochloric acid or gastric secretion in the stomach after the stomach has emptied itself. In other words, the gastric secretion continues beyond the normal period. Dr Dragstedt, I think, has proved that if the nerve supply of the stomach is interrupted the sense of discomfort is at least temporarily relieved.

The other phase of the discussion, namely, that the patient must have had proper medical treatment before any surgical procedure is carried out, is obvious, but I have yet to learn what proper medical treatment is. I have a great deal of respect for Dr Wangensteen's careful work on the physiology of the stomach, but he was not able to find that diet made one particle of difference. The patient got along just as well on raw carrots as on pap. That also has been true in my experience.

However, if one is to give proper medical treatment, one must take cognizance of the facts in Dr Dragstedt's work and interrupt at their source, the cerebral cortex, the impulses to the stomach that are disastrous and are responsible for the continuance of gastric secretion. This brings me to the business of psychosomatic therapy. Before one can evaluate medical management, these patients must have their difficulties straightened out. Their tensions and their anxieties must be relieved.

"Proper medical treatment," so far as anxiety is concerned, has been something like this. "You take a dose of this pap every two hours. God help you if it doesn't do you any good, for then we are going to have to cut your stomach out." That is supposed to relieve the patient's anxiety!

I wish to repeat, all this work is extremely beneficial if one does not take too literally the New Testament mandate of cutting off the offending member.

DR. ROBERT L SANDERS, Memphis, Tenn.: Being host of the association, I should be seen and not heard. Nevertheless, I appreciate the privilege of taking part in this discussion.

My colleagues and I have had only 15 cases, but, from the clinical results obtained thus far, I believe that vagotomy is on solid ground.

Dr Zimmermann has emphasized the psychoneurotic factor in duodenal ulcer. If this is the primary factor, division of the nerve pathways should be sound therapy from the etiologic and physiologic, as well as from the clinical, standpoint. It serves to remove the stimulus which gives rise to gastric hypermotility, hypersecretion and hyperacidity, which, in turn, produce and maintain ulcer.

It is of little practical importance whether hyperacidity, hypersecretion or hypermotility is first in the synthesis of ulcer, though it is probable that hypermotility is first, since the symptoms are induced directly by pylorospasm. Moreover, other operations involving section of nerves, such as sympathectomy for dysmenorrhea, are based on the same principle. When the tissues are relaxed, the pain ceases. In a few of our cases we have made an observation which indicates that hyperacidity plays a lesser role, i.e., the postoperative acids may be little reduced, or not at all, under the stimulus of insulin hypoglycemia and yet the patient may be free of pain from his ulcer. One may assume that hypermotility is responsible for hypersecretion and that the latter is, in reality, chiefly active in the production and maintenance of ulcer. This is in accord with Dragstedt's view that the chief secretory abnormality is the production of an excessive amount of acid during periods of fasting, particularly at night.

In any event, vagotomy is a rational indirect attack on the ulcer. It gives one an idea of what might be accomplished by attack on the source of the ulcer, that is, by preventing stimulation of the nerve centers themselves. It may be that in the not far distant future some agent will be discovered which serves this purpose effectively and permanently.

Whether one employs the abdominal or the thoracic approach is an individual matter. Being an abdominal surgeon, I prefer to divide the nerve trunks through the abdomen. The thoracic surgeon feels that he can better reach them through the chest. At my age, I do not want to become a thoracic surgeon, I am going to stick to abdominal surgery. I want to look at the ulcer, to feel it and if it is in the stomach, to find out whether or no it is malignant. If it is a duodenal ulcer, I want to see whether it is posterior or anterior or both, and whether it is producing obstruction or is likely to do so, if so, I want to do a gastroenterostomy.

I have had no difficulty in dividing the nerve trunks through the abdomen. Before attempting the procedure, I tried it on cadavers, using the abdominal approach, then I opened the chest to see whether all the trunks had been sectioned. I could not find any intact fibers anywhere. This convinced me that the operation could be performed as successfully through the abdomen as though the chest. Vagotomy should not be attempted by the untrained surgeon, however, as it is not always easy to isolate the nerve trunks. Furthermore, in some patients there are more than two vagus trunks, and one or more is likely to be overlooked.

Although I do not believe vagotomy is the final answer to the problem of ulcer, it seems to be preferable to gastrectomy in that the technic is relatively simple, the risk is less and nutritional disturbances are likely to be fewer. The nerves having been divided through their trunks and the ulcer having healed, one has good reason to expect that the symptomatic results will be lasting.

DR CHARLES W MAYO, Rochester, Minn. I rise to a point in question as to the existence of any method at present that is adequate to determine within two weeks after operation whether or not a surgeon has cut all the branches of the vagus nerve. In my opinion, the passage of time, at least to the point of two to four months, with tests for the absence of acids is the only justifiable means of concluding that all branches of the vagus nerve have been resected.

Those of us who have done or are doing thyroid surgery have seen a condition known as traumatic temporary paralysis of the recurrent laryngeal nerve and have known the function of the nerve to return after a week, or sometimes as late as two to three months after operation.

Because a review of records made at present might otherwise lead to a source of error in future considerations of this subject, it should be emphasized that sufficient time must elapse before it can be recorded that all nerves were cut at operation.

DR R. RUSSELL BEST, Omaha I have been interested in the vagus nerve for several years. In fact, about fifteen years ago I reported on some experiments. Since then, I have tried to follow the literature regarding the effect of the vagus on the gastrointestinal tract, and I am sorry to have to disagree with our genial host, but I do not believe that vagotomy as a treatment of gastric ulcer is fundamentally sound.

In experiments carried out fifteen years ago, in which I tried to determine whether peptic ulcer is lymphogenic or neurogenic, I injected staphylococci into the wall of the stomach, in an attempt to produce ulcers in rabbits. I found out that these rabbits died of a very small injection of staphylococci within about four days. Examination of the nerve did not show vagitis or any disturbance of the lymphatic system.

I then conducted experiments on dogs in which I laid strips of magnesium sulfate on the vagus nerve in the neck in the hope that I might produce the ulcer which Cushing had presented as secondary to tumor of the brain.

However, when I placed the strips of magnesium sulfate on both vagus nerves of the neck, the dogs, unfortunately, died. Four died because the strips were placed on both nerves, thus blocking the heart, I knew, therefore, that I was stimulating the vagus nerves.

In the next 6 dogs, I made gastric pouches and laid the strips on one nerve, but I was unable to produce ulcer. I then lost my interest in the relation of the vagus nerve to the stomach. Since then, a great deal of research has been done, I believe that it might well be summarized in the statement by Cryder and Thomas, in their recent report on their experiments. They found that within two years all their animals had a return of normal pancreatic secretion after section of the vagus nerves.

This observation probably leads to the conclusion that the stomach or the gastrointestinal tract is autonomous. That is, after the vagus nerves are cut, the patient can still eat, he still has gastric juices and the stomach empties. I do not believe one should try to arrive at a conclusion about this operation before another three or five years. Many surgeons will probably become more enthusiastic about vagotomy or vagectomy, but I believe one should withhold the expression of any definite opinion at this time.

DR FRANK HAMILTON, Washington, D. C. The series of postradiation gastric ulcers is too small to permit conclusions as to the etiologic factors. There seems to be a direct relation between a heavy dose of radiation delivered to the region of the stomach and the formation of a radiation ulcer. There also appears to be an individual tumor sensitivity, as well as a personal sensitivity, to the effects of radiation. However, radiation ulcer did not develop in any patient who had a dose of less than 5,000 r applied to any one area. Since the arbitrary limitation of the dose to this amount, no new radiation ulcers have appeared at this hospital. My colleagues and I, however, are still seeing, and operating in, occasional cases of excessive fibrosis with intestinal obstruction following heavy doses of radiation. How long we shall continue to see cases of this type is a matter of conjecture.

In answer to Dr Schmidt's question concerning necrosis at the site of anastomosis Fortunately, in my small series, I have not yet encountered that complication Perhaps one reason is that I have always been able to make the anastomosis through reasonably normal tissue On the gastric side of the anastomosis the effect of radiation seems to be sharply limited, and I have always been able to resect the stomach through normal tissue at a higher level than that at which the radiation effect apparently exists, as shown by the slides On the jejunal side of the anastomosis, I have always been able to find a reasonably normal appearing loop of jejunum which was used for the anastomosis This anastomosis was followed by a jejunojejunostomy when indicated At any rate thus far none of the anastomoses have broken down but again it must be emphasized that the series is small and definite conclusions cannot be drawn

DR WALTERMAN WALTERS, Rochester, Minn Dr Mayo has brought out an important point which I had not considered previously In the study of the results of the insulin test, the only deduction possible is that a rise in gastric secretion fifty minutes after injection of sufficient insulin to reduce the blood sugar below 40 mg per hundred cubic centimeters indicates that all the branches of the vagus nerves have not been cut This increase occurred in 1 of my cases and in some of the other cases which we have studied I am glad that Dr Best brought out the points which he did, for experimental evidence presented by Hartzell and Vanzant and others indicates rather definitely that gastric secretion and gastric acids return within two years after resection of the vagus nerves

Why does the atony which develops two, three or four days after gastric resection, and in some cases persists for two weeks, subside This return to normal tone is probably to be explained by an inherent autonomic mechanism in the stomach, which is independent of the vagus nerve Moreover the histamine acts directly on the secretory mechanism of the acid secreting glands of the stomach but not on the vagus This is an important factor in the necessity of a good dietary regimen which aims to lower and neutralize gastric acidity in cases of peptic ulcer Certain substances such as tobacco, alcohol and hot peppers directly stimulate the gastric glands to secrete acid and do not act through the vagus nerves It is well to remember also, that only the central mechanism of gastric stimulation is removed when the vagus nerves are cut

I wish to call attention to several cases and to show some slides In 1 case I performed gastric neurectomy for a small gastric ulcer about nine weeks ago The ulcer was not removed The patient felt fine for two weeks after operation at which time he returned home He then began to have a feeling of fullness after meals and returned for further examination A roentgenogram taken about 1 o'clock in the afternoon eight weeks after the operation revealed a dilated stomach There was so much secretion in the stomach five hours after a test meal that the roentgenologist could not tell whether or not the ulcer had healed Paloro spasms and hypomotility of the small intestine were noted on roentgenoscopic examination In other words, the finely coordinated mechanism of the muscles of the stomach, the pylorus and the small intestine was absent

In another case gastric neurectomy had been performed for a large gastric ulcer The neurectomy had been complete as determined by the insulin test The large gastric ulcer which the patient had prior to operation is shown in the roentgenogram (left side of slide), and a roentgenogram made several months later reveals the recurring gastric ulcer (right side of slide) The patient had achlorhydria after operation, but with recurrence of the ulcer the gastric acid reappeared in increasing amounts He has also had bleeding from the ulcer

I should like to mention the immediate relief of pain which is said to occur after gastric neurectomy. Many surgeons have noticed the relief of pain which occurs when a patient with an active, painful ulcer rests in the hospital for a time before operation. I found years ago that unless I told the patient before hospitalization that he would think he was cured at the end of a week in the hospital, before operation, he would want to leave the hospital and not stay for his operation.

Then, too, a certain degree of inflammation regresses spontaneously. To emphasize this point, I call attention to a number of patients with gastric lesions which the surgeon believed at the time of exploration to be inoperable and malignant. Seven-tenths per cent of these patients have lived longer than five years since exploration. In one-half the cases the lesion was proved to be malignant by biopsy. In the other half, no biopsy was made, and the lesion apparently was inflammatory and had healed spontaneously.

I have a three minute motion picture showing the technic of transabdominal gastric neurectomy. Yesterday Dr. Sanders called attention to the value of placing a tube in the esophagus. The procedure is helpful, but it is well to pull the tube up high in the esophagus after the main vagus trunks have been resected because it interferes with palpation of the smaller branches of the nerves on the esophagus. (Motion picture.)

There is a tendency for all nerve structures to regenerate. However, in some of Hartzell's and Vanzant's dogs examined two years after resection of the vagus nerves regeneration had not occurred.

It is my belief that if the vagus nerves can be accurately resected just above the diaphragm, they can be resected as well just below the diaphragm. In the 8 per cent of cases in which multiple nerves are present, it seems to me the same trouble in locating all the branches will be encountered with the thoracic as with the abdominal approach. The value of exploration of the ulcer and the other abdominal structures which is possible with abdominal approach cannot be minimized.

DR. HAROLD L. THOMPSON, Los Angeles. I have nothing to add except to call your attention again to the point that my paper is the factual report on a sampling from two and one-half years' work in gastric surgery at the Los Angeles General Hospital. The method was to take 100 unselected cases in one group and 50 unselected cases in another group. The results of this study are discussed in our article (Thompson, H. L., and Prout, H. Surgical Treatment of Peptic Ulcer, Recent Experience at Los Angeles General Hospital, ARCH SURG 54:390-413 [April] 1947).

THE MEDULLARY NAIL

Presentation of a New Type and Report of a Case

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INTRAMEDULLARY internal fixation in the form of wires or bone grafts has been used for many years Kuntscher in 1940¹ was apparently the first to use a so-called nail or bar in the shafts of long bones which traversed the length and width of the canal, thereby controlling angulation, lateral displacement and torque. The original Kuntscher nail is a V-shaped bar of V2A stainless steel of such a size as to be easily driven into the medullary canal of the particular bone under treatment.

In devising the medullary nail, Kuntscher has produced a form of fixation for shaft fractures analogous to that supplied by the nails used so frequently and successfully in fractures of the femoral neck. His method therefore has the same advantages, i.e., no external fixation is necessary, the joints are kept mobile and the patient may be ambulatory in a relatively short time.

In the six years since Kuntscher's original report this method has been used extensively in Europe, with gratifying results. Maatz and Reich² reported a series of over 200 cases, while Bohler³ has analyzed 400 cases.

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Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec 5 1946 by invitation. The paper was read by Dr. Dana M Street, Chief of Orthopedic Surgery Section Kennedy Veterans Administration Hospital.

1 Kuntscher, G Zentralbl f Chir 67 1145 (June) 1940

2 Maatz, R, and Reich, H Beitr z Klin Chir 174 358 385 (May) 1943

3 Böhler, L Treatment of Fractures in Peace and in War ed 8 Vienna Wilhelm Maudrich, 1942

In his early cases Kuntscher inserted the nail retrograde into the marrow cavity of the proximal fragment by means of an open reduction. The nail was driven proximally through the canal and out through the greater trochanter of the femur until the distal end was at the fracture site. He then reduced the fracture and drove the nail on down the medullary canal of the distal fragment. In later cases he found that the nail could be inserted directly through the trochanter, the fragments brought into alignment under the fluoroscope and the nail then driven into the distal fragment without resorting to open reduction.

There have been several modifications in the technic and the various devices used to facilitate the introduction or extraction of the nail. The widening of the canal in the distal and proximal thirds of a bone allows a certain degree of lateral displacement in fractures in these locations. Maatz⁴ has overcome this by using a double nail consisting of two half-round, trough-shaped nails. These are inserted through a window in the cortex, usually in the lateral wall. The distal or proximal ends of the nails, as the case requires, are made to diverge to keep them in close apposition to the inner surface of the cortex. Herzog⁵ has produced a lever device to aid in the closed reduction of the fracture. Stör⁶ described a special tool for use in extracting the nail.

Although Kuntscher's method has been much used in Europe, there has been, owing to the war, little knowledge of it on this continent, and its advantages are still not widely recognized. We wish to present in this paper 4 cases in which we inserted a medullary nail and which, we believe, well illustrate the indications for its use.

In these cases we have used nails of a somewhat different pattern from the original Kuntscher nails (fig. 1). These, designed by one of us (H. H.), are diamond shaped in cross section rather than V shaped. The metal composing them is chrome-nickel stainless steel of the following composition:

Chromium	17.0
Nickel	7.0
Manganese	2.5-0.2
Silicon	1.5-0.2
Copper	0.5
Phosphorus	0.4
Carbon	0.12

REPORT OF CASES

CASE 1—C. E., a white man aged 25, was injured while signaling to make a left turn. He was admitted to the hospital on Sept. 15, 1945, with a comminuted fracture of the left humeral shaft, compound badly comminuted elbow and com-

4 Maatz, R. Zentralbl f Chir 70:1641-1649 (Nov 13) 1943.

5 Herzog, K. Zentralbl f Chir 70:1656 (Nov 13) 1943.

6 Stör, O. Zentralbl f Chir 70:754 (May 22) 1943.

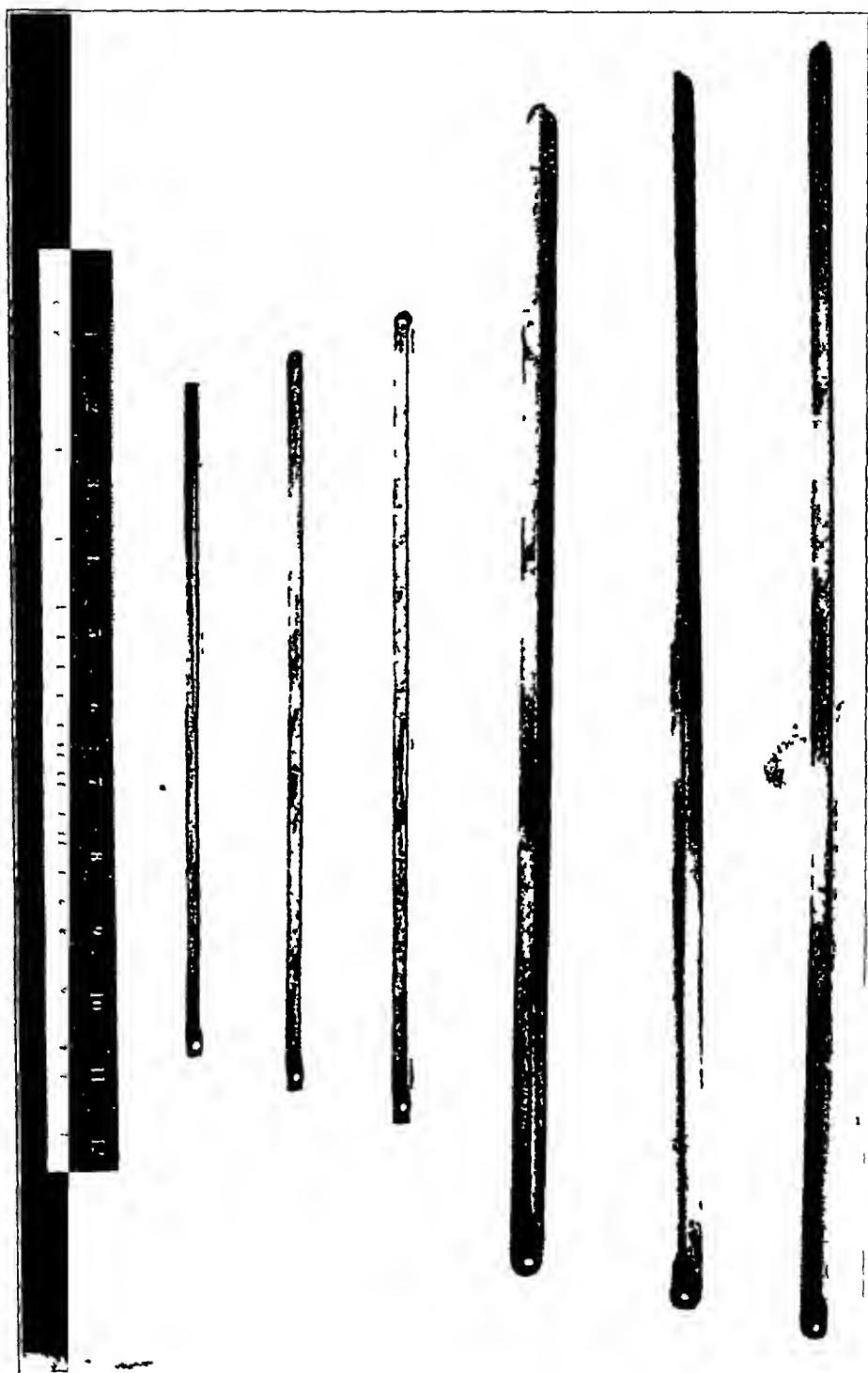


Fig. 1—Medullary nails with diamond cross section. Larger one smaller for humerus.

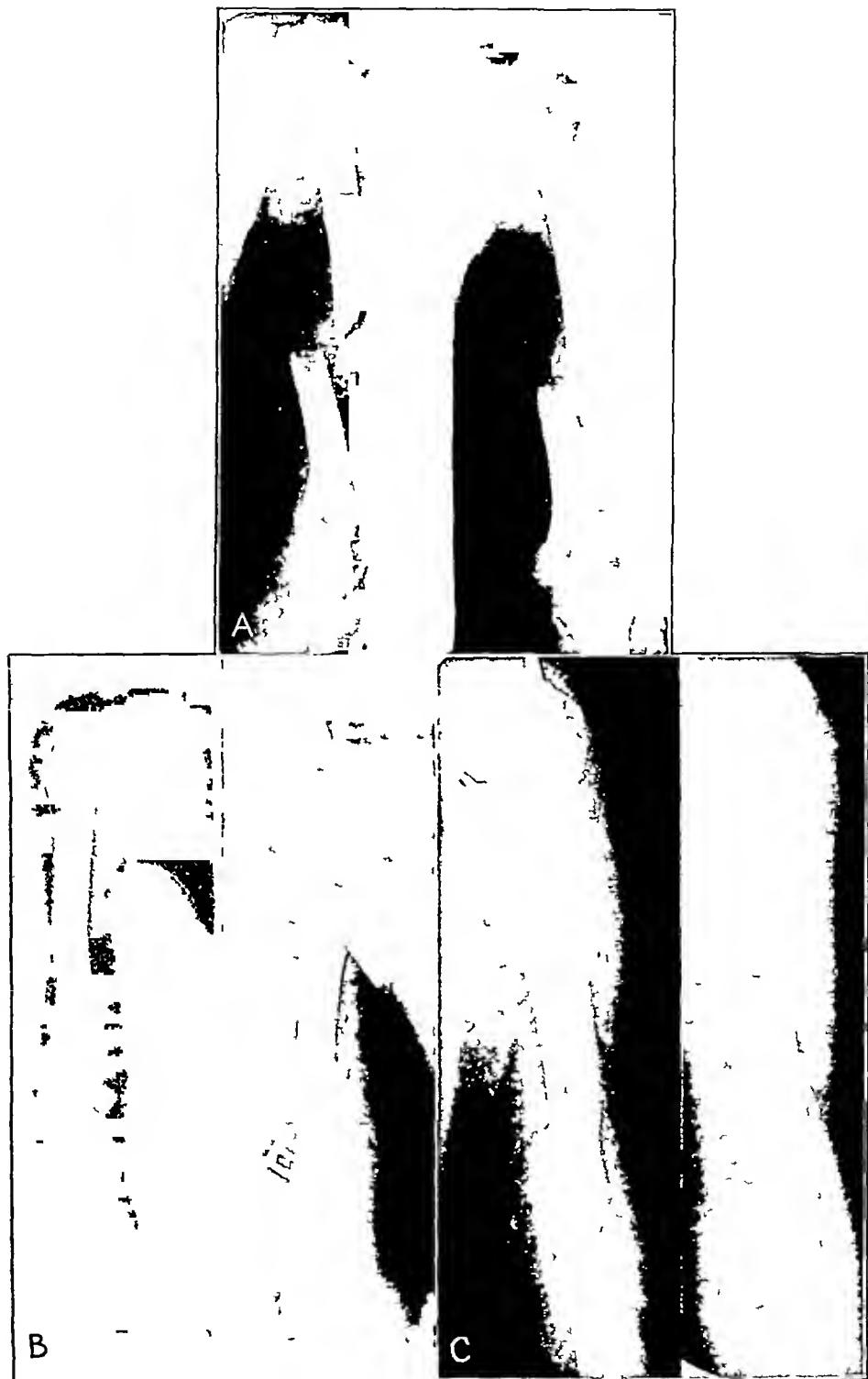


Fig 2 (case 1).—*A*, fracture six weeks old, prior to operation *B*, appearance following insertion of medullary nail *C*, solid union fourteen weeks after operation

pound comminuted fracture of both bones of the forearm. The compound fractures were debrided, and a plate was applied to the ulna, the olecranon wired and a hanging cast applied. At the end of six weeks, the position of the fractured humerus was still unsatisfactory and union was slow, we were anxious to mobilize the elbow (fig 2A). An open reduction was therefore performed, and a nail was inserted through the greater tubercle of the humerus extending down in the medullary canal to within 1.25 inches (3 cm) from the elbow joint. Fixation was solid in regard to both lateral displacement and rotation, obviating the use of a cast. The postoperative roentgenogram (fig 2B) shows the reduction maintained by the nail. After fourteen weeks (fig 2C) the fracture lines appeared solid and ready for extraction of the nail.

CASE 2—H I, a white youth aged 19, fractured his patella and had an open reduction. Three months later he was in an automobile accident, sustaining a compound refracture of the patella and in addition a fracture of the femoral shaft (fig 3A). He was admitted to the hospital on Dec. 7, 1945, the day of the second injury. The wound was debrided, the distal fragment of the patella excised, the ligaments sutured and skeletal traction applied to the distal end of the femur. Even after two weeks the fractured femur was still so painful that he could not be persuaded to do quadriceps setting or to move his knee at all. An open reduction was then performed and a nail inserted from the greater trochanter to within 3 inches (7.6 cm) from the knee joint. Fixation was extremely solid, and no cast was necessary. Motion of the knee was begun the day after operation and was quickly restored, with no pain in the thigh. He was allowed up in a wheel chair in two weeks, partial weight bearing with crutches in three weeks and full weight bearing in five weeks. Abundant callus was already present after three weeks (fig 3B) and solid healing after seventeen weeks (fig 3C). The nail could have been withdrawn, but since there were no symptoms it was decided to leave it in for another two or three months.

CASE 3—D H, a white man aged 28, was admitted from another hospital on Nov 23, 1945, six weeks after an airplane crash. In this he sustained a compound transverse fracture of one femur and a simple comminuted fracture of the other. In the latter there were multiple transverse fracture lines forming two intermediate fragments resembling sections of pipe and measuring 3 and 5 inches (7.6 and 12.7 cm) in length. The position in skeletal traction was unsatisfactory (fig 4A). The compound femur was treated by plating, and when the patient's condition permitted, a nail was threaded down the comminuted femur. A cast was applied because the distal fragment was too short to be securely held by the nail. A composite picture (fig 4B) shows the position of the entire femur postoperatively. Diffuse, poorly calcified callus was visible at twelve weeks with the cast removed (fig 4C).

CASE 4—H Y, a white man aged 23, was admitted to the hospital on Jan 5, 1946, with a simple fracture of the middle third of the right femur (fig 5A). Open reduction was performed because of unsatisfactory position in traction and a medullary nail was inserted. The patient was allowed to bend his knee immediately after operation and maintained good motion and musculature. He was up in a wheel chair in two weeks and was bearing partial weight in three weeks and full weight in five weeks. Good callus was present at three weeks (fig 5B). The nail was removed after fifteen weeks because of dull pain in the knee, with immediate relief. Full weight bearing without support was continued after removal of the nail. Figure 5C shows the massive new bone present a year and eight months.



Fig. 3 (case 2)—*A*, before operation *B* good callus after three weeks
C, solid union after seventeen weeks

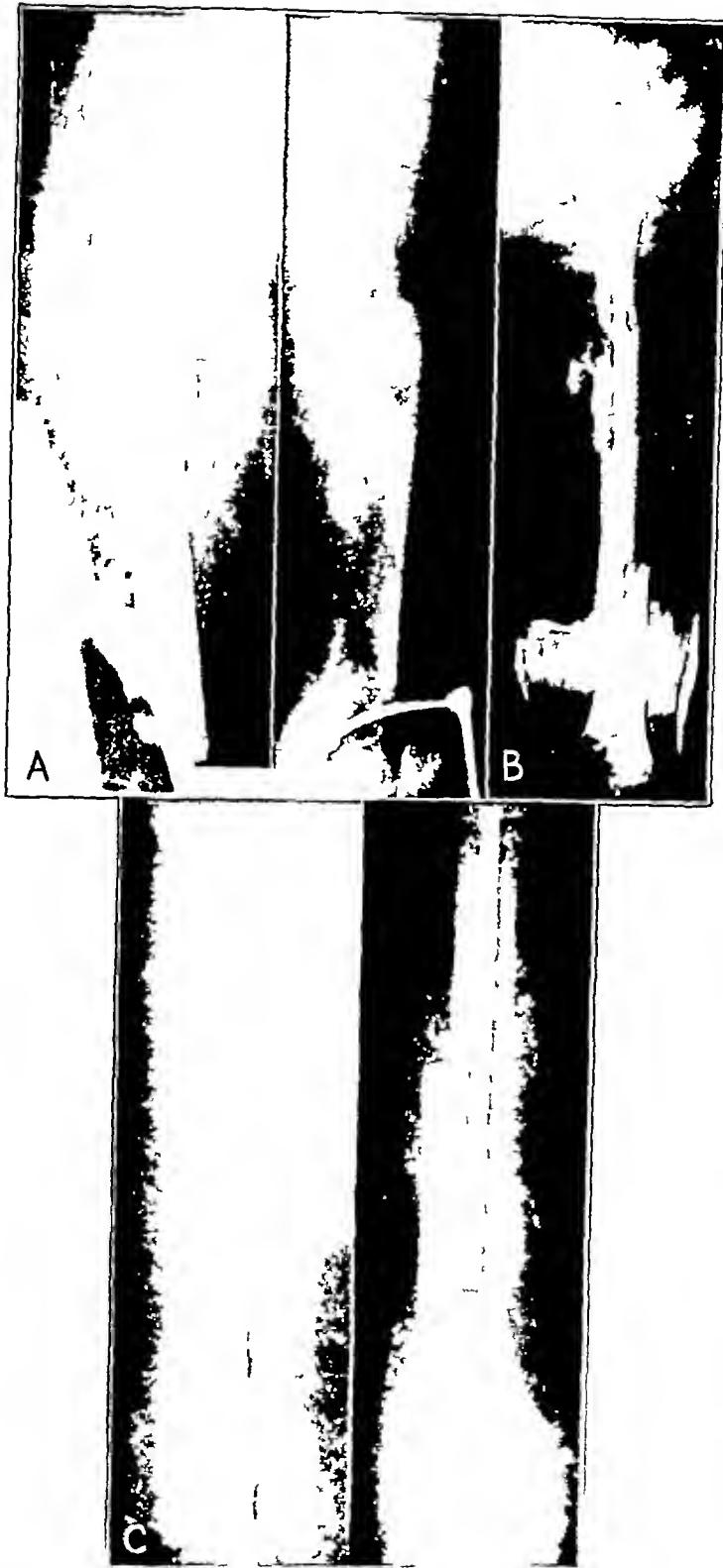


Fig. 4 (case 3) — 1 preoperative appearance of the fracture. *B*, *C*, *D* to show entire length of femur after insertion of nail. *C*, *D*, call's 1 weeks



Fig 5 (case 4).—*A*, preoperative appearance. *B*, good callus after three weeks. *C*, solid union eight months after insertion of nail and four months after its removal.

COMMENT

Indications for Use of the Method—These cases, although few in number, clearly show the validity of the advantages originally claimed by Kuntscher. The fixation is solid, and no cast is necessary (if the fracture is in the middle third of the femur or middle half of the humerus). Motion of the adjacent joints can be started immediately after insertion of the nail. For this reason, motion need not be restored because it is not lost, and muscles do not require rehabilitation because atrophy does not occur. The patient can be out of bed in two weeks and can be bearing partial weight in three weeks and full weight in six weeks in the average case. The lengthy periods of hospitalization so frequent in fractures of the femur are therefore unnecessary, and elderly patients become ambulatory before onset of hypostatic pneumonia.

This method is particularly suited to the treatment of comminuted fractures in which there are multiple transverse fracture lines, the fragments being threaded on the nail-like beads. Rotation and torque stress are controlled by the nail, and apposition is maintained by muscle tone. The technic is simpler than multiple plates or a single long plate, since these involve many drill holes and the insertion of a dozen or more screws.

The method is not indicated for fractures near the end of a bone. The increased diameter of the medullary canal in such fractures allows lateral displacement, and the short fragment has insufficient hold on the nail. We feel that the method is also contraindicated in compound fractures because of the extensive potential field of contamination. However, this will have to be determined by experience over a period of years.

In 3 of these cases (1, 2 and 3) the callus formation was apparent as early as and in amount equal to that in closed reductions (Case 3 presents different problems which will be discussed separately). The callus was not delayed in a manner frequently seen with plate fixation, and no absorption was noted such as is seen in methods of pin fixation. This we attributed, as did Kuntscher, to the anatomic apposition rigidly maintained by control of torque and displacement and also to the physiologic pressure between the ends of the bone exerted by the normal pull of the muscles. The method, therefore, instead of being nonphysiologic as it might at first appear, may in reality be the most physiologic of any method of skeletal fixation as yet devised.

In case 3 the callus was considerably less abundant. There are several factors which may account for this. The operation was performed eight weeks after injury, or after the time when the maximum formation of callus normally occurs. Callus was found to be scant at the time of operation. There was an associated fracture of a large bone

other than the one nailed. The fragments were segmental in nature. The relative importance of these factors is not within the scope of this discussion.

Technic.—In the cases presented, open reductions were performed for two reasons. First, accurate reduction was insured. Second, we considered that there was risk of fat embolism in the closed method. A nail measuring 45 cm in length and 20 sq mm in cross section displaces about 2 teaspoons of fatty marrow. This must be extruded at the fracture site. We consider this pool of fat a real potential danger and prefer to wash it out with ether.

It has been our experience that the retrograde method of inserting the nail through the proximal fragment is technically simpler than inserting it directly through the greater trochanter of the femur.

Type of Nail.—The modification of Dr. Maatz, while theoretically good, requires that two nails be especially constructed for each case; also a window is necessary in the side of the shaft. The diamond-shaped nail which we have used differs from the Kuntscher nail in that it spans the diameter of the canal rather than three chords. It provides extremely rigid fixation, while at the same time it contacts the inner surface (as viewed in cross section) at only two points instead of three. It therefore leaves more of the surface of the canal unmolested.

The choice of metal is of course important. It must not bend under the force of the adductors plus adduction stress of weight bearing since removal of a bent nail is difficult. It must be resilient but not brittle since a broken nail would also present a problem in its removal. It must also be as nearly isoelectric as possible. We chose stainless steel as the metal best suiting these requirements. The two nails thus far removed still showed a high polish. Although the pain in the last patient was attributed to reaction about the nail, it was still snug and required driving with a mallet to remove it.

SUMMARY

Treatment of fractures of the shaft of long bones by means of a medullary nail was introduced by Küntscher in 1940 and has since been extensively used in Europe. Its use is indicated for simple fractures in the middle third of the femur or middle half of the humerus (a) with multiple segmental fragments, (b) with associated fracture into the adjacent knee or elbow joint and (c) in elderly persons.

Open reduction is preferred to closed reduction because of danger from fat embolism.

A new type of nail is presented (diamond shaped).

SURGICAL RELIEF OF PAIN IN PARAPLEGIC PATIENTS

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FROM the recent worldwide conflict approximately 2,000 persons returned to this country with severe injuries to the spinal cord and spinal nerves. Of these, some 600 have been under our care for varying periods. Recent years have brought the wholesale discard of older concepts of paraplegic care, and the life expectancy of the average patient with severe injury of the spinal cord has been lengthened from about eighteen months to perhaps a normal one. In consequence of the renewed hope for this type of patient, the administration of drugs which produce addiction for the relief of pain can no longer be countenanced. It is our firm belief that pain can kill, if not outright as in a case recorded by Tinsley,¹ then at least insidiously through its continued action in bringing about starvation. For the purpose of simplification, pain in the paraplegic patient can be classified into three types. Usually more than one of these elements will be present in the individual case.

CLASSIFICATION

1 *Somatic Pain*—Somatic pain is that pain characterized by intermittency, sharpness and conformation to dermatome patterns. It is found most frequently in patients with injury to the cruda equina and affects the dermatomes in which no sensation is present. Thus it can be likened to a phantom pain. In some instances the hyperalgesia of the segments lying directly above the site of injury may amount to actual pain.

2 *Sympathetic Pain*—Sympathetic pain is characterized by its constancy, by its dull, aching or burning nature and by its vague reference to such regions as the back of the leg. This includes the so-called visceral pain.

3 *Psychic Pain*—Psychic pain has no definite characterizing features and does not lend itself to definition. In the philosophic sense one

— Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec. 5, 1946.

From the Paraplegic Section of the Surgical Service, Kershaw Veterans Administration Hospital, Memphis, Tenn.

1 Tinsley M. Compound Injuries of the Spinal Cord I. Vol. 306-309 (July) 1946. 3

might find the description of pain as the absence of pleasurable sensations (Schopenhauer) more elucidating than the many vague terms of modern psychology. Because these patients have suffered severe mental trauma, it is necessary to speak of the diagnosis of pain.

DIAGNOSIS OF PAIN

In figure 1 is shown a patient who suffered a gunshot wound of his abdomen in combat. The missile perforated his large bowel and the lower spinal canal, producing severe damage to the cauda equina. At the time this photograph was taken, nineteen months had elapsed since injury and the use of narcotics had been withdrawn over the last three



Fig 1.—Patient with lesion at the cauda equina suffered in combat nineteen months previously. Somatic pain was the dominant complaint, all types of pain in the legs and trunk were relieved by bilateral cordotomy performed high up.

months. Of special interest are the position and the facies. The drawn expression—"hang-dog" look—and the sharply flexed posture are typical of a patient suffering severe pain. Nutrition is poor despite frequent transfusions, special proteins and numerous efforts to stimulate the appetite. Once this picture of true somatic pain has been seen, the purely "psychic pain" can be recognized quickly. With this type it is observed that only as the physician approaches the bedside is the patient stirred from cheerful conversation with his bedfellows. His appeals for relief of pain know no bounds, except that surgical relief is usually resisted. On adoption of the policy that pain requiring

morphine for relief should be attacked surgically, many of the pseudopains cease to be problems. The patient suffering somatic pain can give a clear description of all aspects of it. Sympathetic pain does not lend itself to such accurate description, but the story fits the pattern of pain of peripheral vascular disease so well that it is also relatively clear. However, the sufferer from pseudopain finds it necessary to use verbiage far beyond the standard of his educational achievements. Long, drawn-out, vague descriptions, evasions of direct questions and the profound lability of emotions will serve to arouse suspicion. Far greater difficulty is encountered in cases which demonstrate combinations of all the types discussed. Several test methods may be used.

(a) Placebo therapy When the psychic component must be considered as a large contributor, a course of placebo therapy will often be of considerable benefit. In highly emotional patients the threat of suicide during such a course has been encountered.

(b) Sympathetic nerve block This should temporarily relieve the sympathetic type of pain. However, since the origin of the pain is probably not peripheral, care should be exercised in evaluating therapy suggested by this procedure.

(c) Procaine hydrochloride anesthesia of "trigger points" This should be used in all cases in which these can be demonstrated.

(d) Caudal or extradural procaine hydrochloride anesthesia This will temporarily relieve somatic pain but often will not influence psychic pain.

(e) Controlled spinal anesthesia This procedure described by Faw and Gotten,² has been used in a modified fashion to demonstrate the likelihood of success of intraspinal procedures.

Each of these test methods may give permanent benefits, especially if they are repeated.

SURGICAL PROCEDURES FOR RELIEF

Surgical procedures for relief include the following:

1 Injection of alcohol into peripheral nerves This procedure has extremely limited application but can be used with temporary success when previous injection with procaine hydrochloride has given relief.

2 Injection of alcohol in the epidural space This procedure has limited use in the paraplegic patient because of the scarring of the dura at the site of injury.

3 Injection of alcohol in the subarachnoid space (Dogliotti). From 1 to 2 cc. of absolute alcohol is injected slowly in the subarachnoid space.

2 Faw, T. and Gotten, N. Controlled Spinal Anesthesia. Its Value in Establishing Appropriate Levels for Cordotomy. Arch Neurol & Psychiat 50: 1276-1281 (Dec.) 1933.

3 Dogliotti, A. M. Traitement des contractures de l'arc rachidien par l'alcoolisation subarachnoidale des racines posteriores au niveau de la moelle epiniere. Presse med 39: 1249-1252 (Nov. 22) 1931.

with the patient lying on the unaffected side, arched at the point at which maximum effect is desired and turned slightly to the back to keep the posterior roots uppermost

4 Sympathectomy Routine lumbar sympathectomy or the Peet,⁴ Adson⁵ or Smithwick⁶ procedures can be utilized. Results in 5 cases have been disappointing enough to warrant hesitation in the utilization of this procedure.

5 Decompressive laminectomy, leaving the dura open. This has less success in late cases than it does in early ones.

6 Dorsal rhizotomy An occasional case will be found in which section of appropriate spinal posterior roots would seem to be indicated. However, success is limited.

7 Chordotomy Section of the anterolateral spinothalamic tracts will be found to be necessary in most cases.

STATISTICS

Analyses of cases at various centers have given data which show large differences in the proportion suffering with pain. At one center only 12 per cent of the patients required special attention to pain. At another the figure jumped to 17 per cent. Astoundingly enough, at a third the indications were that over 50 per cent had problematic pain. Reevaluation of this last group soon showed that careful diagnosis, assurance, occupation and placebo therapy reduced this proportion to approximately 15 per cent. Few patients with lesions above the cauda equina have real pain. Careful analysis will reveal that unpleasant sensations are interpreted as pain, and custom causes these patients to request hypodermic injections for relief. However, there remains a large number of patients, almost all of them with lesions of the cauda equina, who face addiction to drugs unless surgical relief is offered. No attempt is made to include the rather numerous acute pains occurring in the course of common ailments.

In the accompanying table the results of the surgical procedures are briefly summarized. In some patients more than one procedure was carried out before relief was obtained. Not all the 600 patients had been under our care for sufficient time to determine the necessity for surgical relief of pain. However, approximately two thirds of them had been under our care for a period of more than six months.

4 Peet, M. M., Woods, W. W., and Braden, S. The Surgical Treatment of Hypertension. Results in Three Hundred and Fifty Consecutive Cases Treated by Bilateral Subdiaphragmatic Splanchnicectomy and Lower Dorsal Ganglionectomy, J. A. M. A. 115:1875-188 (Nov 30) 1940.

5 Adson, A. W., and Brown, G. E. Treatment of Raynaud's Disease by Lumbar Ramisection and Ganglionectomy and Perivascular Sympathetic Neurectomy of the Common Iliacs, J. A. M. A. 84:1908-1910 (June 20) 1925.

6 Smithwick, R. Surgical Intervention on the Sympathetic Nervous System for Peripheral Vascular Disease, Arch. Surg. 40:286-306 (Feb.) 1940.

COMMENT

The failure of any surgical procedure short of chordotomy can be predicted with relative certainty. All paraplegic patients have suffered injury to the contents of the spinal canal, and efforts aimed at the periphery disregard the seat of the pathologic changes. The failure of dorsal rhizotomy comes from the fact that only the projection site is removed, whereas the pathologic phenomena are present at or in the spinal cord. Sympathectomy is likewise doomed to failure since the typical pain is often present in patients showing complete sympathectomy effect in the lower limbs. In the arms, success of sympathectomy can be predicted in cases in which the injury included the brachial plexus. Emphasis for the view that sympathectomy will usually fail is provided by the observation that patients with complete transections at or above the third dorsal dermatome do not complain of pain in the legs or viscera.

Results of Surgical Procedures in Cases of Paraplegia

Procedure	Number of Cases	Pain			Comment
		Pain Abolished	Pain Im- proved	Unchanged at Six Weeks	
Decompressive laminectomy	6	0	0	5	Does not include cases in which the operation was done soon after injury
Dorsal rhizotomy	3	0	3	0	Somatic pain was abolished but sympathetic pain remained
Sympathectomy	5	0	2	3	Two improved patient had lumbodorsal (D10-L1) sympathectomy
Chordotomy	40	4	9	2	See last 6 patients who operated on twice

Two exceptions to this statement must be recorded. Figure 2 shows photomicrographs taken of a 23 cm piece of spinal cord between the second and third thoracic roots removed from a patient who had suffered a clinically complete lesion twenty months prior to operation. His sensory level was the fourth thoracic dermatome, and he complained bitterly of pain in the right leg. Numerous gitter cells and inflammatory signs are seen. No normal structure can be distinguished. Post-operatively, there was little diminution of pain until triamcinolone acetonide and finally histamine desensitization were used. In a second case there were gross findings of considerable inflammatory changes in the second thoracic dermatome without relief of pain in the trunk despite section of the anterior half of the cord. These cases are presented

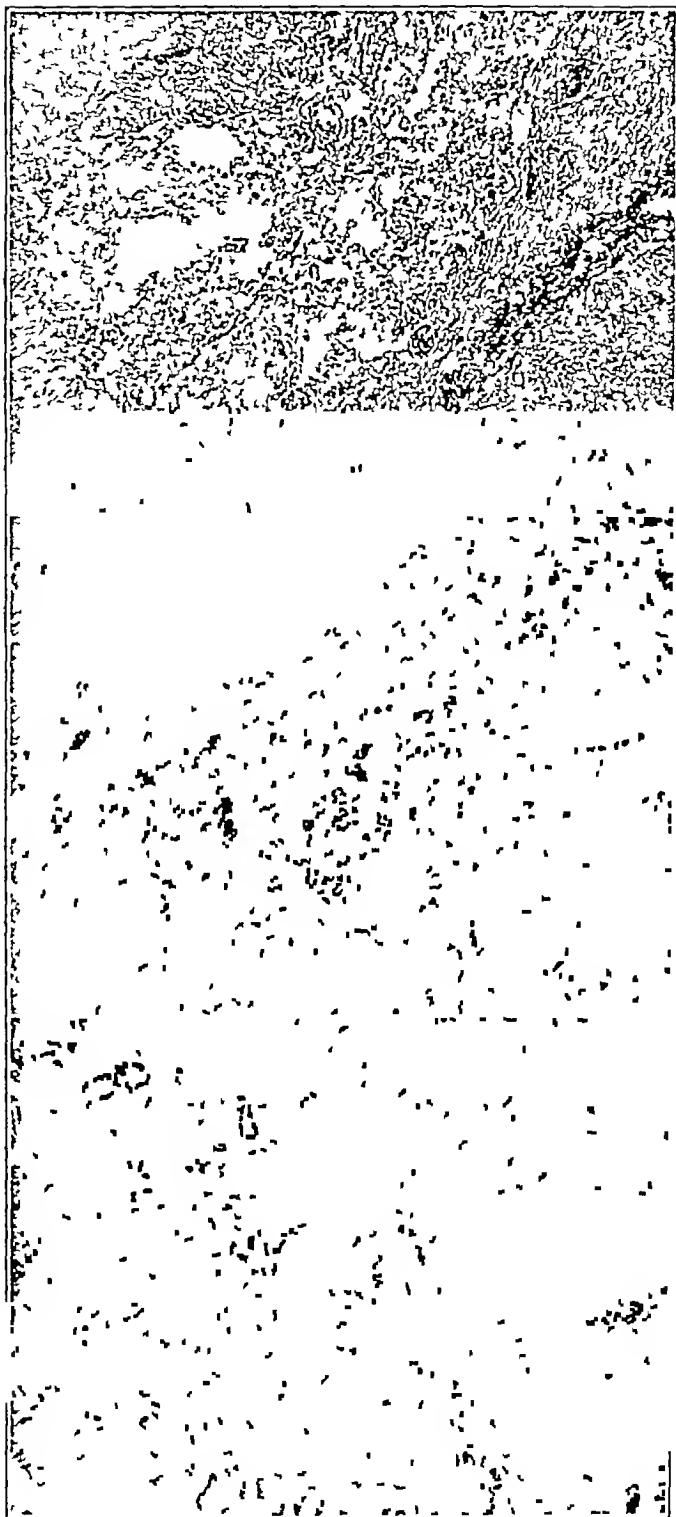


Fig 2.—Photomicrographs of a segment of spinal cord from between the second and third thoracic roots in a patient with complete paraplegia suffered twenty months prior to operation. Pain was present in the right leg from the time of injury and was not relieved by the operation.

the first and second dorsal roots has uniformly abolished all types of pain in the legs or viscera. Consequently, it is felt that the surgical procedure of choice for relief of pain in the majority of patients is bilateral chordotomy between the first and second dorsal roots.

Of the 45 patients undergoing chordotomy listed in the table, 24 were operated on by us. In 6 of these it was done twice because there was failure to relieve the pain and inadequate levels of analgesia were demonstrable after the first procedure. The 2 patients listed as not improved after six weeks had no change in their levels of analgesia postoperatively. Each of the patients with only partial relief had inadequate levels of analgesia on at least one side.

All patients in whom the level of analgesia reached above the dermatome level of the referred pain had complete relief of somatic pain. All patients with levels of analgesia at or above the third dorsal dermatome had complete relief of somatic and sympathetic pain.

Differential chordotomy was done in 4 patients centered at the sixth dorsal vertebra. Each of these obtained temporary relief only. Unilateral chordotomy was done in 12 cases, but this served only to unmask the pain in the other leg, and the other side had to be sectioned. We have been gradually performing chordotomies higher in the spinal canal, until we now do them between the first and second thoracic roots in all cases. This has been necessary, since early operations which gave levels of analgesia at any point below the fourth thoracic dermatome only relieved the somatic pain and often did not relieve the sympathetic pain. Fortunately, a large percentage of the earlier patients subjected to chordotomy either did not have sympathetic pain or were able to tolerate it. The postoperative discomfort from the procedure as carried out higher up is much less, and the execution is no more difficult. No operative deaths occurred in this group.

Local anesthesia is preferred, since the adequacy of the procedure can be assured on the operating table by sensory examination. In patients who do not permit the use of local anesthesia failure to produce adequate levels of analgesia has required that the operation be repeated. This is usually done on the tenth day after the first procedure.

Complications encountered include involvement of the bladder and spasticity. No permanent involvement of the bladder has been produced. However, several patients lost pain as an index of fulness of the bladder after the procedure. Of the 45 patients listed, 7 had some degree of postoperative spasticity, but none had permanent loss of motion present preoperatively. In only 1 case was this spasticity of any concern.

The surgical technic used by us follows the pattern laid down by Frazier⁷ and elaborated by others.⁸ Figure 3 (drawn by one of the

⁷ Frazier, C. H. Section of the Anterolateral Columns of the Spinal Cord for Relief of Pain. A Report of Six Cases, Arch Neurol & Psychiat 4: 137-147 (Aug.) 1920. (Footnotes continued on next page)

patients) shows the ideal course of the knife in chordotomy. Although the section must closely approach the gray matter, we do not feel that, as in the dog,⁸ there is any necessity of entering it. This view is substantiated by Hyndman^{8b} We have used successively deeper and more anterior sections in almost all our cases and find that as the section is continued medially and anteriorly the level is raised. We have made no observations of the temperatures. In the region between the first and second thoracic roots a depth of 5 mm must be reached, and the tip of the knife must emerge at least 2 mm anterior to the point of emergence of the anterior root to insure adequate levels of analgesia and relief of pain. Unfortunately, the severe degree of paralysis already present in almost all cases does not permit accurate observation of the loss of motor function. In bilateral sections the incisions should be placed at least 1 cm apart to prevent the production of a complete transection.

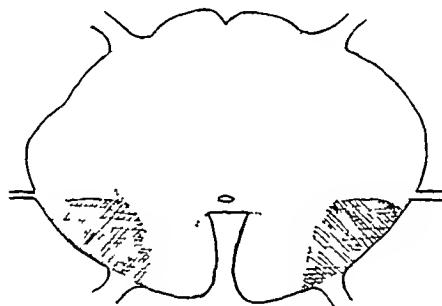


Fig 3.—Diagrammatic sketch of spinal cord to show approximate course of the knife in cordotomy. This is a 13 mm cross section at D2.

SUMMARY

Bilateral chordotomy performed high up, below the arm area, is presented as the best answer to the problem of somatic and sympathetic pain in the trunk and lower limbs of patients with injury of the spinal cord.

Diagnostic procedures for differentiation of the types of pain are listed. Caution in the analysis of pain is urged. The central origin of the pain is emphasized.

⁸ (a) Kahn, E. A. Anterolateral Chordotomy for Intractable Pain, J. A. M. A. **100** 1925-1928 (June 17) 1933 (b) Hyndman, O. R., and Van Epps, C. Possibility of Differential Section of the Spinothalamic Tract. A Clinical and Histologic Study, Arch. Surg. **38** 1036-1053 (June) 1939

⁹ Davis, L., Hart, J. T., and Cram, R. C. The Pathway for Visceral Afferent Impulses Within the Spinal Cord. II Experimental Dilatation of the Biliary Ducts, Surg., Gynec. & Obst. **48** 647-651 (May) 1929

FOREIGN BODIES IN THE INTESTINAL TRACT

THOMAS J SNODGRASS, M D

JANESVILLE, WIS

THE TOOTHPICK is still widely used in America. It accompanies the Martini, the Manhattan, the Old-Fashioned, the canape and the club sandwich. The integrity of the last popular item with its many unstable layers requires the holding power of the toothpick. One equipped with artificial dentures may not have to use the toothpick as such, but with the loss of sensory stimuli in the roof of the mouth and the gums it is much easier to ingest unknowingly a foreign body in a morsel of food. Cocktails, canapes and club sandwiches are conducive to the careless handling of toothpicks, and that more are not arrested somewhere along the intestinal tract is due only to the marvelous mechanism in the intestinal tube which makes it possible to manage foreign bodies in great quantity without serious damage. This mechanism was described by Carp¹ in 1927. He described the experimental work of Exner, showing that large quantities of sharp foreign bodies, such as spicules of glass and needles, can be introduced into the stomach of dogs and cats, and the intestinal tract can turn and expel them, blunt end first, within twenty-four hours without injury to the intestinal mucosa. Carp¹ further described the points of arrest as (a) the junction of the second and the third part of the duodenum, (b) the ileocecal region, (c) the lumen of the appendix, (d) the junction of the cecum and the ascending colon and (e) the flexures and haustra of the large intestine.

Carp¹ reported a series of 48 proved cases of foreign bodies in the intestine occurring in the Presbyterian Hospital in New York between 1915 and 1926, all the bodies having been swallowed and many different types encountered. In most of them in which the patient could be followed the body was evacuated without untoward symptoms. Of the 31 cases with follow-up observation, the body was passed in 25, or 80 per cent.

From the Pember Nuzum Clinic.

Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec 7, 1946

¹ Carp, L. Foreign Bodies in the Intestines, Ann Surg 85 575-591 (April) 1927

That foreign bodies are arrested in the intestinal tract and do cause serious damage is attested by the numerous reports from the literature. However, cases in which the toothpick is the cause of the trouble are comparatively few. While most foreign bodies are swallowed accidentally, it is not infrequent practice among the insane and certain professional persons to make a business of eating glass and other objects.

Cannady,² in 1931, in a discussion of this subject, reported the case of a woman aged 26 who was operated on three times within a year. Each time a large number of foreign bodies were removed, and the last time 140 such objects, mostly wire nails, screws, and the like, were removed from the stomach. In his conclusions, he stated that "while there have been several reported cases of perforation of the cecum by wooden toothpicks, perforation of the viscera by nails or other pointed metal objects is a comparatively rare occurrence."

While the present discussion applies to foreign bodies in general, the case reports are limited to those of toothpicks and similar slivers of wood. Although chewing toothpicks is a common practice, I have found no case in which a person made a business of eating toothpicks, and in only 1 case did the victim recall the time at which the object was swallowed.

In 1926, Ginzburg and Beller³ reported 12 cases of nonmetallic foreign bodies in the intestinal tract. 6 of fishbones, 5 of chicken bones and 1 of a toothpick. They found the cecum and the flexures of the colon the most common sites of arrest, and the conditions most frequently noted were (a) acute peritonitis, (b) localized intestinal abscess, (c) intra-abdominal inflammatory tumor, (d) inflammatory tumor of the abdominal wall, (e) abscess of the abdominal wall and (f) inflammation and obstruction in a hernial sac.

MacManus,⁴ in 1941, collected 95 cases from the literature, excluding cases of perforation by ingested blunt foreign bodies. Of these, toothpicks and splinters of wood caused perforation in 9 cases, or in more than 9 per cent of the whole series. He found the predominance of perforations in the lower iliac and the cecal region. Aside from a large number which occurred in the appendix and in Meckel's diverticulum, the perforations in 20 of the 95 cases were in these regions. In 50 per cent of the cases the duration of symptoms ranged from a few hours to two weeks. The mortality rate in the surgical period before 1900 was 53.5

2 Cannady, J. E. Foreign Bodies in the Stomach and Intestines, Ann. Surg. 94: 218-232 (Aug.) 1931.

3 Ginzburg, L., and Beller, A. J. The Clinical Manifestations of Non-metallic Perforating Intestinal Foreign Bodies, Ann. Surg. 86: 928-939 (Dec.) 1926.

4 MacManus, J. E. Perforations of the Intestine by Ingested Foreign Bodies, Am. J. Surg. 53: 393-402 (Sept.) 1941.

per cent, and in the period after 1900 it dropped to 10 per cent. MacManus⁴ also reported a case of his own in which a toothpick was the cause of the perforation.

Melville,⁵ in 1940, in discussing perforation of the intestinal tract by foreign bodies, stated that the condition is not common and apparently has never been diagnosed before operation or autopsy, because of the close similarity to acute appendicitis in most cases. In others, the clinical features have been too confusing to suggest the origin of the peritonitis. The confusion in the latter group may be due to the rarity of similar cases in any one surgeon's experience. To aid in the diagnosis of the condition, Melville postulated a theoretic complex consisting of (*a*) colic, (*b*) peritonitis and (*c*) a lower abdominal locus, and expressed the belief that many acute cases do approximate this concept.

In a review of the literature, I have collected 20 cases in which a toothpick was the source of the trouble and have added 1 case of my own. In 13 of these cases the trouble was diagnosed as acute appendicitis and in 2 as abscess of the abdominal wall. In 1 case the diagnosis was peritonitis, and in 4 it was not determined before operation.

The site of perforation in 10 cases was the cecum, in 3 cases, Meckel's diverticulum, and in 2 cases, the duodenum. In 1 case the toothpick was found free in the peritoneal cavity close to the duodenum, and in a case reported by Rivers and Davison⁶ the point of the toothpick was in a duodenal ulcer 6 cm below the pylorus and the other end projected into the stomach. In 2 cases the perforation was in the ileum, and in a case reported by Maxeiner,⁷ of this society, the toothpick was observed penetrating a diverticulum of the sigmoid and had caused a pelvic abscess. In 1 case the toothpick had penetrated the transverse colon, and in another, the small intestine and abdominal wall.

In 10 cases an abscess was present. In 9 cases there was evidence of considerable inflammation but no abscess, and in 1 case the presence of abscess was not mentioned.

In 13 cases the source of the foreign body was unknown. In a case reported by Vestal,⁸ a child aged 9 had swallowed a toothpick while drinking a glass of water nine days previously. She did not tell her parents of this seemingly difficult feat. Wallis⁹ reported a case in which

5 Melville, C B. Perforation of Small Intestine by Swallowed Foreign Bodies. *Australian & New Zealand J Surg* **10** 146-156 (Oct) 1940.

6 Rivers, A B., and Davison, H L. Foreign Bodies in the Stomach. *Ann. Int. Med.* **4** 742-751 (Jan) 1931.

7 Eitel, G D. Ingested Foreign Bodies in the Gastro-Intestinal Tract Requiring Surgical Removal. *Minnesota Med.* **18** 52-59 (Jan) 1935.

8 Vestal, P W. Perforation of Cecum by Foreign Bodies with a Report of a Case Simulating Appendicitis. *New England J. Med.* **203** 1199-1200 (Dec 11) 1930.

9 Wallis, T B. Perforation of the Cecum by a Toothpick. Case Report. *J. Florida M. A.* **17** 127-129 (Sept.) 1930.

a man was in the habit of using toothpicks after a meal and then falling asleep with the toothpick in his mouth. His wife usually removed it, but if not he would awaken with the toothpick still in his mouth. Wallis⁹ further stated, "Let me caution you. If you are a toothpick user, be sure that your wife is faithful in her duty, or tie a string to your toothpick when it is not in use." This is probably the answer to the safety toothpick. McClintic¹⁰ said that his patient worked at odd times in a restaurant and was in the habit of hurriedly eating three decker sandwiches held together with toothpicks. Henderson and Gaston¹¹ reported a case in which the man identified the splinter of wood as being a part of the seasoning used in cooking the spaghetti which he had eaten six hours before the beginning of his symptoms. Zieman¹² stated that his patient ate veal birds pinned together with toothpicks and wore upper and lower dentures, suggesting the possibility of eating the toothpick without feeling it in his mouth. In 1 case a "hot dog" pinned together with toothpicks was to blame. Evans and Hanlon¹³ concluded that the habit of chewing toothpicks is not only inelegant but dangerous.

All the 20 patients recovered. One author noted that the patient had a stormy convalescence. Three cases were of children and 17 of adults. The perforating object was identified as a toothpick in 17 cases and as wood splinters, similar in size and shape, in 3 cases. The present report adds a case to this small group.

REPORT OF A CASE

A man, aged 51 registered at the clinic on June 20, 1945, for repair of an incisional hernia which had been diagnosed elsewhere. He gave no history of previous illness. Shortly after Thanksgiving Day in 1944 he experienced sharp abdominal pain. Several days later he entered a hospital elsewhere and was observed for four days before operation. A diagnosis of acute appendicitis was made. Exploration was done through a right rectus incision and the appendix removed. He was in the hospital a little over two weeks and soon after the operation was fitted with a girdle, which he had worn since. Later a bulging and bunch were discovered in the wound, and he felt that the incision did not look right. He gained weight after the operation, reaching 220 pounds (99.8 Kg), but with diet and medication he reduced his weight to 179 pounds (81.2 Kg), and at the time of his examination at the clinic he weighed 190 pounds (86.2 Kg). He also described a sharp, penetrating pain and a sensation of tearing in the scar. He had no nausea or vomiting. He stated that several weeks before entering the hospital the second

10 McClintic, B S Perforation of Intestines by Foreign Bodies, Mil Surgeon 75 75-78 (Aug) 1934

11 Henderson, F F, and Gaston, E A Ingested Foreign Body in the Gastrointestinal Tract, Arch Surg 36 66-95 (Jan) 1938

12 Zieman, S A Perforating Foreign Body of Cecum, U S Nav M Bull 43 1103-1105 (July) 1943

13 Evans, R L, and Hanlon, G D Perforation of a Meckel's Diverticulum by a Portion of a Toothpick, Guthrie Clin Bull 12 102-104 (Jan) 1943

time he had strained himself in lifting and had much pain in the region of the scar, resembling the pain of appendicitis. He said that it had been necessary for him to take cathartics to keep his bowels moving. Examination revealed a large, healthy-appearing man, about 5 feet 10 inches (178 cm) in height. He had a complete upper denture, his lower teeth were fairly good. He had a scar on the right shoulder and a recent scar in the lower part of the right rectus muscle, with wide separation of the muscles and some bulging, increased with coughing and straining, in the upper part of the wound. The blood pressure, pulse and temperature were within normal limits. The urine and the blood chemistry were normal. The Wassermann reaction of the blood was negative. The blood counts were normal, showing a leukocyte count of only 7,600 and no change in the differential count. Pain and soreness in the wound were so definite and had been so prolonged that exploration appeared advisable.

Operation was performed on June 23, with the patient under anesthesia induced with cyclopropane, oxygen and ether. The old scar in the right rectus muscle was dissected out through an elliptic incision, and exploration revealed a wide separation of the upper layer of fascia and evidence of a good deal of low grade inflammation. The sac was opened, and many adhesions were encountered between the intestinal coils and the sac. After these adhesions were separated, more adhesions were observed between the loops of the bowel. During the course of the manipulation an object was noted in the bowel which tented it up and almost protruded through it. After further separation of the adhesions, the intestine was opened transversely and an object $2\frac{3}{4}$ inches (7 cm) long, in the shape of a toothpick, was removed. This object had perforated posteriorly into the mesentery and worked back and forth in this loop of ileum, possibly perforating the abdominal wall at several points, at least the heavy scar tissue indicated that this might have occurred. The opening of the intestine was closed. Additional adhesions were separated, 5 Gm of sulfanilamide was placed in the peritoneal cavity, the muscle was dissected out, and the wound was closed, using chromic surgical gut sutures in the peritoneum, and interrupted wire sutures in the fascial layers, the suture line being reenforced with continuous fascial strips previously taken from the right thigh and laced back and forth after the method of Gallie. The subcutaneous layer was closed with interrupted cotton sutures and the skin with clips. The patient made a rather rapid and uneventful recovery and was dismissed from the hospital on July 5. When he was seen a month later, he appeared to have an excellent result and was free from symptoms.

How he acquired this troublesome item in his diet he was not certain. He did not use toothpicks in the usual way, for he had artificial dentures. He revealed that he had been accustomed to eat club sandwiches in the past and admitted that it was entirely possible that he may have ingested this toothpick with the sandwich inadvertently, not detecting it because the roof of his mouth was protected with the denture. This explanation seems logical.

COMMENT

It may be said that accidentally ingested foreign bodies generally cause little trouble, but when they do it is usually because they are arrested and perforate at one of the angles of the intestinal tract, the ileocecal region being by far the most common site. The symptoms generally are such that acute appendicitis or appendical abscess is suspected. The most commonly used instrument in the mouth, the wooden

toothpick, appears to be the least common cause of perforation or other complications incident to the presence of a foreign body in the intestinal tract.

The literature has been reviewed and 20 cases collected in which a toothpick, or a splinter of wood similar to a toothpick, was the cause of perforation or other complications in the intestinal tract (table). The data are analyzed in the following tabulation.

Diagnosis	
Acute appendicitis	13
Abscess in the abdominal wall	2
Peritonitis	1
Undetermined	4
	20
Perforation	
Cecum	10
Meckel's diverticulum	3
Duodenum	2
Ileum	2
Diverticulum of the sigmoid	1
Transverse colon	1
Intestine and abdominal wall	1
	20
Abscess	
Present	10
Absent	9
Unstated	1
	20
Source of foreign body	
Unknown	13
Drank in glass of water	1
Fell asleep with toothpick in mouth	1
Three decker sandwich	1
Spaghetti seasoning	1
Veal birds	1
Hot dog	1
Chewing toothpicks	1
	20

SUMMARY OF CASES FROM THE LITERATURE

In 1926 Ginzburg and Beller³ reported the case (case 4 in their series) of a man aged 40 with a diagnosis of acute appendicitis with abscess. The operation revealed a normal appendix and a retrocolic abscess, with a fragment of toothpick 1 inch (25 cm) long perforating the posterior wall of the upper part of the cecum and lying outside of the lumen. The perforation was closed and drained, and the patient recovered.

In 1930 Durman and Belz¹⁴ reported the case of a woman aged 48 with pain of six months' duration in the left side of the abdomen.

¹⁴ Durman, C. D., and Belz, F. Abscess from Swallowed Toothpick, J. A. M. A. 94: 1830 (June 7) 1930.

Data on Cases in the Literature

Date	Author	Diagnosis	Sex	Age Yr	Location	Object	Abscess	Site of Perforation	Source of Foreign Body	Outcome
1926	Ginzburg and Bellcr. ³	Acute appendicitis with abscess	M	40	Retrocecal	Toothpick	Yes	Cecum	Unknown	Recovery
1930	Durman and Bellz. ¹⁴	Abcess of abdominal wall	F	48	Left side of abdomen	Toothpick	Yes	Intestine and abdominal wall	Unknown	Recovery
1930	Vestal. ⁶	Acute appendicitis	F	9	Right lower quadrant	Toothpick	Yes	Cecum	In glass of water	Recovery
1930	Walls. ⁹	Acute appendicitis with abscess	M	?	Ileocecal junction	Toothpick	Yes	Cecum	Patient fell asleep with toothpick in mouth	Recovery
1930	McLanahan. ¹⁰	Appendicitis Undetermined	M	44	Cecum	Toothpick	Yes	Cecum	Unknown	Recovery
1931	Rivers and Davison. ⁶	Acute appendicitis	F	?	Duodenum	Toothpick	?	Duodenal ulcer	Unknown	Recovery
1931	McClintle. ¹⁰	Pelvic abscess, ruptured appendix	M	34	Cecum and appendix pelvis	Toothpick	No	Cecum	Three decker sandwich	Recovery
1935	Varrelner. ⁷	Acute appendicitis	F	?	?	Toothpick	Yes	Diverticulum of sigmoid	Unknown	Recovery
1937	Domavan. ¹⁰	Acute appendicitis	M	11	Meckel's diverticulum	Wood splinter	No	Meckel's diverticulum	Unknown	Recovery
1939	Henderson and Groat. ¹¹	Near right, over Poupart's ligament Prin. In upper right abdominal quadrant	M	8	Ileum	Wood splinter	No	Ileum	Unknown	Recovery
1939	Henderson and Groat. ¹¹	Peritonitis right lower quadrant	M	43	-ity near stomach	Wood splinter	No	First part of duodenum	Spongheotti seasoning	Recovery
1940	McVille. ⁵	Peritonitis right lower quadrant	F	?	Right iliac fossa	Toothpick	Yes	Ileum, two places	Unknown	Recovery, stormy convales- cence
1941	Vitellius. ⁴	Appendicitis	M	62	Cecum, lateral wall	Toothpick	Yes	Cecum	Unknown	Recovery
1942	Kirrett and Landor. ¹⁷	Appendicitis	M	?	Terminal part of ileum	Toothpick	No	Cecum	Unknown	Recovery
1942	Geochrig. ⁸	Abcess of lower part of abdominal obstruc- tion of bowel	M	61	Ileum and transverse colon	Toothpick	Yes	Transverse colon, obstruc- ting cecum	Unknown	Recovery
1944	Leimann. ¹²	Ruptured appendix	F	?	Cecum and internal wall	Toothpick	Yes	Cecum	Veal hiris	Recovery
1945	Fox and Hamilton. ¹⁷	Acute appendicitis	M	29	Terminal part of ileum	Toothpick	No	Meckel's diverticulum	Chewing toothpicks	Recovery
1947	Loring and Hamilton. ¹³ (1949)	Acute appendicitis	F	?	Cecum	Toothpick	No	Cecum	Unknown	Recovery
1947	Loring and Hamilton. ¹³ (1949)	Not stated	F	?	Terminal part of ileum	Toothpick	No	Meckel's diverticulum	Hot dog	Recovery
1947	Hutchins. ¹⁰	Acute appendicitis	M	47	Right colic fissure	Toothpick	No	Cecum	Unknown	Recovery

Exploration revealed an abscess in the abdominal wall, with a toothpick 4 cm long in the center of it. The patient could not recall swallowing the object.

The same year Vestal⁸ reported the case of a white girl aged 9, who was admitted to the hospital with a diagnosis of acute appendicitis, onset was with mild pain three days before and severe abdominal pain and nausea two days before. Examination showed slight tenderness and muscular spasm in the right lower abdominal quadrant, and an indefinite mass was made out in the region of the appendix. The leukocyte count was 18,000, with 82 per cent polymorphonuclear leukocytes. A preoperative diagnosis of acute appendicitis with probable perforation and abscess formation was made. Operation revealed an abscess in the right lower quadrant of the abdomen, and resting on the floor of the cavity of the abscess was a slender, pale yellow piece of material, which on further examination proved to be an ordinary wooden toothpick. It had perforated the cecum on the anterior lateral aspect at a level with, and almost opposite, the ileocecal valve. It had penetrated through the intestinal wall only part of its length and was unbroken except for a slight "greenstick fracture" near its perforating end. The perforation was closed, the appendix removed and the abscess cavity drained, and the patient made a satisfactory recovery. After operation the child remembered having swallowed the toothpick while drinking water about nine days prior to her admission to the hospital. This case is one of the few in which the patient had any recollection of having swallowed the toothpick.

Wallis,⁹ in 1930, reported the case of a man who was taken with a knifelike pain in the right side, the pain coming on in paroxysms, lasting a few minutes, then going away and recurring again. Two days after the first attack he was again seized with severe paroxysms of pain accompanied with nausea. He was transported 4 miles (6.4 kilometers) to a physician, and a diagnosis of appendicitis was made. He was given $\frac{1}{2}$ grain (0.032 Gm) of morphine and then taken 78 miles (126.5 kilometers), by automobile, to a hospital. On arrival he was in great pain. The right rectus muscle was tense and rigid, and the point of maximum tenderness was halfway between the anterior superior spine and the umbilicus. The leukocyte count was 16,000, and a diagnosis of acute appendicitis with possible rupture was made. When the abdomen was opened, there was an escape of serosanguineous fluid with a fecal odor, and in the region of the ileocecal junction a small, hard object the size of a match was to be felt in the abdomen. On removal from the cavity it was found to be a whole toothpick, round, pointed and stained with fecal material. At a point on the posterior surface of the cecum, about halfway between the ileocecal junction and the

appendix, was observed a perforation about the size of a toothpick, with an area of induration around it. The opening was closed, the appendix removed and the abdomen closed with drainage. Recovery was uneventful. The patient denied having swallowed a toothpick but stated that he frequently used toothpicks after a meal and sometimes dropped asleep with one in his mouth. If his wife did not remove it, he would find it in his mouth on awakening. He also occasionally ate sandwiches which were held together with toothpicks. Evidently, he either ate the sandwich, including the toothpick, or fell asleep with the toothpick in his mouth and swallowed it while sleeping. Wallis¹⁵ pointed out three points of interest: (a) the danger of using toothpicks in making sandwiches, the danger of sleeping with them in the mouth and the possibility of unconsciously swallowing them, (b) the peculiar location of the perforation, which was so closely associated with the appendix that the condition was diagnosed as ruptured appendix, and (c) the finding of the toothpick, which the author, realizing the difficulty frequently encountered in removing small foreign bodies from other locations in the body, regarded as a matter of luck and not skill.

In the same year McLanahan¹⁶ reported the case of a man aged 44 who entered the hospital stating that on the previous day he first noted a dull pain in the right side of the abdomen. At times it was increased in intensity, with extreme tenderness in the right lower quadrant and a moderate degree of muscle spasm. A tentative diagnosis of appendicitis was made. Operation revealed a foreign body within the lumen of the cecum. Evidence of a small abscess was seen along the lateral wall of the cecum, with a small perforation leading into the abscess, and projecting through the hole was a small foreign body which proved to be a toothpick. Drainage and recovery followed. The patient had no recollection of swallowing the foreign body.

In 1931 Rivers and Davison⁶ reported the case of a young woman (case 8 in their series) who came to the clinic because of nausea, vomiting and pain, with exacerbations of severe pain in the right lower abdominal quadrant. Soreness and pain occasionally radiated through to the back. Two years later the patient returned to the clinic complaining of spells of vomiting, regurgitation of greenish yellow, bitter fluid, and sometimes particles of undigested food, before and after meals. Dizziness always preceded vomiting. Menstruation made the vomiting worse. The function of the bowel was normal and the appetite good. Before vomiting the patient would have a sharp, knifelike pain in the left side. She thought she noticed some jaundice after vomiting. The

15 McLanahan, S. Perforation of the Cecum by a Toothpick Simulating Acute Appendicitis. *J. A. M. A.* 95:1424 (Nov. 8) 1930.

pain was indefinitely situated. Exploration revealed a perforated duodenal ulcer about 4 cm in diameter. It was buried in adhesions and was situated about 6 cm below the pylorus, one point of a wooden toothpick was in the ulcer, and the other projected into the stomach. The upper part of the abdomen was filled with adhesions. Chronic appendicitis was present.

In 1934, McClintic¹⁰ reviewed the literature and reported an additional case, that of a soldier aged 34 who was admitted to a station hospital complaining of abdominal pain. He had been in good health up to noon of the preceding day, at which time he was seized with severe pain across the lower part of the abdomen. Two hours later he took an effervescent saline cathartic. His bowels moved, and after this the abdominal pain became severer and was localized in the right lower quadrant. There was no nausea or vomiting at any time. The diagnosis was acute appendicitis, and the patient was sent to the hospital by ambulance. The abdomen showed mild localized tenderness under deep pressure over McBurney's point. There was no rigidity or rebound tenderness. The leukocyte count was 12,400. Because of the mild symptoms and the relief afforded by an enema, the operation was postponed for further observation. The next day the tenderness increased, was constant and was definitely localized. The preoperative diagnosis of acute appendicitis was made. Operation showed that the appendix was lateral to the cecum and attached throughout its full length by adhesions. Plastic lymph covered both the appendix and the lateral wall of the cecum. In this plastic lymph and in the cecum and the appendix opposite the ileocecal valve was observed a common wooden toothpick. The appendix was removed, with the stump inverted. Perforation was not observed in the appendix or in the cecum. The lateral wall of the cecum was raw and inflamed. The patient made a satisfactory recovery, and during convalescence was questioned about the toothpick. He had no recollection of ever having swallowed one but stated that when he was off duty he helped in a relative's restaurant and that frequently during the past year he had eaten three-decker sandwiches held together with large toothpicks. Because of the location of the foreign body and the absence of a hole in the appendix, the author believes that in this case the cecum was the part that was perforated, however, the site of perforation was not discovered. The patient made an uneventful recovery.

In the discussion on Eitel's paper,⁷ Dr S R Maxeiner reported 7 cases, 1 of which (case 5) was referred for pelvic abscess. After an acute attack of abdominal pain which in every way resembled that of appendicitis, a tentative diagnosis of pelvic abscess due to ruptured appendix was made. However, on opening the abdomen the appendix

was observed to be normal, and when the abscess was opened a toothpick was observed to be penetrating a diverticulum of the sigmoid. The patient made an uneventful recovery.

In 1937 Donavan¹⁶ reported the case of a boy aged 11, on whom operation was performed through McBurney's incision, with a diagnosis of acute appendicitis. A Meckel diverticulum, perforated by a wooden splinter (toothpick not specified) was removed.

In 1938 Henderson and Gaston¹¹ stated that between June 1, 1915 and Oct 1, 1936, 800 cases of foreign bodies in the gastrointestinal tract had been observed at the Boston City Hospital, but, because the records were unsuitable for study, this series had to be narrowed down to 105 in which records could be carefully studied. Of this group, only 2 are of interest in this paper, and in these cases a splinter of wood appeared to be the offending object. A toothpick as a foreign body was not definitely identified. One case was that an 8 year old school boy, admitted to the hospital with abdominal pain of twenty-four hours' duration. A tender mass was felt just above Poupart's ligament. Exploration through a right rectus incision showed a normal appendix, but further exploration revealed a deeply injected piece of small bowel through which a wooden splinter had perforated. The surrounding intestine and mesentery were covered with fibrin, but there was no pus. The foreign body was removed through an opening in the bowel and was closed with a purse-string suture. The patient had an uneventful recovery.

Henderson and Gaston¹¹ also reported the case of a man aged 45 who entered the hospital complaining of abdominal pain of twenty-four hours' duration. He stated that a month previously he had had a period of four days in which he had suffered from abdominal cramps and diarrhea, which he attributed to food. Twenty-four hours before this he had felt well and had eaten a hearty meal of spaghetti, on the same day he was seized with sudden, severe epigastric pain, sharp and stabbing, and not radiating. Physical examination showed extreme tenderness in the epigastrium, with spasm of involuntary muscle throughout the upper portion of the abdomen. Tenderness was more pronounced just to the right of the midline. The leukocyte count was 20 000. Fluoroscopic examination showed no evidence of pneumoperitoneum. Operation through an upper right rectus incision revealed a moderate amount of clear serous fluid in the peritoneal cavity. A piece of wood 1½ inches (3.8 cm.) long was seen near the stomach. The omentum was adherent to the anterior wall of the pylorus, more particularly the first portion of the duodenum, and the point of perforation could not be found.

16. Donavan, E. J. Meckel's Diverticulum Perforated by Foreign Body. Ann Surg. 106: 953-954 (Nov.) 1937.

undoubtedly being under the adherent omentum. The wound was closed, with drainage. During convalescence the patient identified the small splinter of wood as being part of the seasoning used in cooking spaghetti, which he had eaten six hours before the onset of his acute symptoms.

In 1940 Melville⁵ reported the case of a woman who one week before consultation had severe pain in the right lower abdominal quadrant. Castor oil aggravated the pain. She had signs of general peritonitis, with maximum tenderness in the right lower quadrant and a palpable mass in the right iliac fossa. Rectal examination revealed maximum tenderness in the right side. A right paramedial incision revealed a large inflammatory mass in the right iliac fossa. The omentum separated from this, and a wooden toothpick 2½ inches (6.3 cm.) in length was noted. It had perforated the ileum in two places. The perforation was closed and the pelvis drained, the patient had a stormy convalescence.

In 1941 McManus⁴ reported the case of a man aged 65 who entered the hospital with generalized abdominal pain of forty-eight hours' duration. Abdominal tenderness was present, rebound tenderness was referred to the right lower quadrant, and exquisite tenderness was elicited just mesial to McBurney's point. A diagnosis of acute appendicitis was made. Operation revealed induration about the cecum. The appendix was less injected and was secondarily involved. Further exploration revealed a walled-off perforation of the lateral wall of the cecum from which a toothpick was protruding. The foreign body was removed, and the perforation was closed and drained, when the patient recovered, he could not recall swallowing the toothpick.

Barrett and Leader,¹⁷ in 1942, reported the case of a white man who entered the hospital complaining of gradually increasing pain in the right lower quadrant and mild diarrhea for the past twenty-four hours. Physical examination revealed an elevation of temperature of 1 degree (F), tenderness and rigidity over the right lower quadrant and an area of spasticity over McBurney's point. The white cell count was 17,000. Operation revealed that the small intestine and cecum were inflamed, and on exposure of the cecum in the region of the terminal portion of the ileum there was observed a perforation from a toothpick, one half of which protruded into the peritoneal cavity and the other half remained in the cecum. The perforation was closed, the appendix removed and the wound closed with drainage. The patient made an uneventful recovery.

In 1943, Goehring¹⁸ reported the case of a Negro aged 63 with cramplike pain around the umbilicus for a duration of ten days. He

17 Barrett, W. D., and Leader, L. R. Perforation of Cecum by Toothpick Case Report and Review of Literature, *Harper Hosp Bull* 1:120-122 (May) 1942

18 Goehring, W. O. A Case of Toothpick Perforation of the Intestines, *Am J M Sc.* 205:807-808 (June) 1943

was treated conservatively for four days. An abscess the size of a grapefruit formed in the lower part of the abdomen and was drained surgically. Twelve days after the patient entered the hospital there was still drainage, along with evidence of obstruction of the small bowel. Operation, performed thirty-six days after admission, revealed a foreign body granuloma containing a toothpick, which had first penetrated the transverse colon, and the ileum had later become impaled on the toothpick.

In 1943 Zieman¹² reported a case with a rather indefinite history, but the patient appeared decidedly ill. There was definite muscular rigidity over the entire lower part of the abdomen, with rebound tenderness referred to McBurney's area, fulminating appendicitis with probable rupture and peritonitis was suspected. When the peritoneal cavity was entered, serosanguineous fluid welled up into the field. The cecum was isolated and delivered, followed by an exceptionally long appendix. The appendix was only slightly injected, but the base of the cecum presented mottling of petechial spots, and a scarified, ulcerated lesion on the lateral aspect of the cecum was discovered. When the colon was rotated laterally, a black foreign body was seen perforating the center of a similar ulcerated area. The object appeared to be a fishbone and was firmly adherent to the bowel, necessitating removal with a hemostat. The appendix was removed, and examination of the foreign body later revealed it to be a toothpick encrusted with fecal deposit. The author stated:

Conjecture as to the possibility of a person swallowing, unknowingly, a full length toothpick brought out certain interesting comments. First the patient had been accustomed to eating veal birds which were rolled and pinned together with toothpicks. The long baking of such morsels may have softened the wood sufficiently to cause it to lose its resistance. That one could swallow such an object betrays the careless mastication of the individual. However, considering the loss of touch sensation that can occur in a patient with upper and lower dentures, it is not only possible, but explanatory, as to the present instance.

In 1943 Evans and Hanlon¹³ reported the case of a man aged 28 who entered the hospital three days after the onset of pain. Pain began in the right lower quadrant and increased in severity, and on the day of admission morphine gave only slight relief. He had nausea but no vomiting. He had two loose, watery bowel movements on the day of admission. A medical diagnosis of duodenal ulcer had been made two years before and treatment given. The temperature was 101 F. Examination revealed tenderness over the entire abdomen but the greatest area of tenderness was over the right lower quadrant. Slight rigidity was present throughout the abdomen. Peristaltic sounds were diminished. Rectal examination revealed tenderness to the right. The leukocyte count

was 16,400, with 93 per cent polymorphonuclear leukocytes. The preoperative diagnosis was acute appendicitis. On opening the abdomen a small amount of cloudy fluid was observed, the appendix was retrocecal, the serosal surface was injected, but the gross appearance did not coincide with the clinical findings. Inspection of the terminal portion of the ileum revealed a Meckel diverticulum $1\frac{1}{2}$ feet (45 cm) from the ileocecal region. The diverticulum was $\frac{3}{4}$ inch (1.9 cm) long and $\frac{5}{8}$ inch (1.6 cm) in diameter. The surface was covered with exudate, and a portion of a toothpick was seen to have perforated the diverticulum. Appendectomy and diverticulectomy were performed, and the patient made an uneventful recovery.

From the same article¹² is taken the report of a patient with a perforation of the cecum by a toothpick. The patient was operated on in the clinic in 1936 by Dr G W Hoff, with recovery. The preoperative diagnosis also was acute appendicitis. Hanlon reported that he had attended the presentation of a case by T A Shallow in November 1940 in which a portion of a toothpick had perforated Meckel's diverticulum after the eating of a hot dog the night before. To date, that is 1943, this case had not been reported.

Hurwicz,¹³ in 1944, reported the case of a man aged 47 who was admitted to the Veterans Administration Facility at Los Angeles, with slight pain in the right lower quadrant. There was no nausea or vomiting or history of gastrointestinal distress. Examination showed extreme tenderness in the right lower quadrant, with rebound tenderness. The white cell count was 11,200. A diagnosis of acute appendicitis was made, and operation was performed soon after his admission. The peritoneal cavity contained a moderate amount of purulent fluid, which was removed by suction. The appendix appeared grossly normal. A long, sharp object was encountered in the right colic gutter, which on delivery proved to be an intact toothpick. A small perforation was observed about $1\frac{1}{2}$ inches (3.8 cm) from the ileocecal junction. Perforation was closed with drainage, the appendix was removed, and the patient made a good recovery. The patient was questioned but was unable to recall having swallowed a toothpick and stated that he seldom used one.

500 West Milwaukee Street

DISCUSSION

DR. ERWIN R SCHMIDT, Madison, Wis. This paper illustrates well the situation that one encounters in the practice of medicine. One meets an unusual case and, after solving it, looks up the literature and finds that a fairly large number

of such cases have been reported over a period of years. They are lost in the literature and, unless one has an inquiring mind, will remain lost. Textbooks usually present reviews of the literature.

The author has emphasized some important points. I did not appreciate the association of dentures and the swallowing of foreign bodies, but I can readily see that the wearing of dentures is a definite factor.

Carp's work shows that the predilection for certain regions in the gastrointestinal tract is what one would suspect. The development of the lesion certainly must be accidental, for all physicians have seen foreign bodies pass through the tract with conservative management. The detection of arrest of the foreign body and the development of symptoms and early pathologic changes often defy the diagnostician. A scout film in obscure cases will often give the first evidence if the object is radiopaque. The history may or may not be helpful. If positive it is helpful; if negative, it means nothing. Often the final diagnosis is made at operation or after examining the specimen.

The first case of a foreign body I have in mind was that of a student at Washington University, during the days of prohibition. The day was rather hot, and the best beer made in St. Louis was Busch's. This fellow had an enormous thirst, he had a way of drinking the beer out of the bottle, opening the bottle and tipping it up, and he could empty it into his stomach without stopping. He had pain after he had drunk his beer that day. He came to the outpatient department and was observed for some time, without a diagnosis being made. Eventually someone took a roentgenogram and found that a sewing needle, the type of needle used to darn socks, had gone in through the esophagus, had penetrated the wall of the esophagus and was sticking into his heart.

I have a slide from a case reported by Dr. A. R. Curreri and Dr. D. W. Melick (*Wisconsin M. J.* 40:192 [March] 1941), showing the foreign body. It was lodged in the appendix and was identified by the department of zoology as the vertebra of a rodent, either that of a squirrel or a rat. The patient had never eaten squirrel—he was not questioned about rat.

The patient gave a history of appendectomy for ruptured appendix three months before admission, followed by a persistent draining sinus. Excision of the fistulous tract was performed, and an abscess developed, which healed after incision and drainage. Two weeks later an intestinal obstruction developed and an abscess recurred in the right lower quadrant. The abscess was drained, and the obstruction improved with conservative management. Nine weeks later the patient was readmitted with a dull pain in the right lower quadrant. During the interval another abscess had formed and had been drained. An exploratory laparotomy showed dense adhesions around the terminal loops of the ileum and the proximal portion of the large bowel. Enmeshed in these adhesions was the appendix. This was removed, and on opening the appendix the vertebra was discovered. The patient made an uneventful recovery.

DR. FRANCIS E. CLOUGH, San Bernardino, Calif. The wooden toothpick is the plebian thing one uses to pick the teeth with. The patrician type that we older fellows remember was a gold toothpick that slid back and forth in a case. Between the patrician and the plebian all types of instruments have been used to pick the teeth.

A few years ago, a young woman with acute appendicitis was brought in on my service. When I opened the abdomen there was the appendix acutely inflamed.

sticking up like a sore thumb. It felt very hard. I could not cut through it with the usual technic. There was something inside. Finally, I dissected through the wall with a sharp knife and pulled the appendix off from a pin.

The story was that the patient had been picking her teeth with a 3 inch (7.5 cm) steel hatpin with a large black head. The pin had been swallowed. It had gone down into the intestinal tract and had entered the appendix, point first. The head was too large to get into the appendix and had stayed in the intestine. I had to open the cecum to withdraw the big head of the pin. The woman made an uneventful recovery.

DR. THOMAS J. SNODGRASS, Janesville, Wis. I wish to thank Dr. Schmidt for his fine discussion and Dr. Clough for presenting this interesting and unusual case. Dr. Clough's case can be admitted to this group of cases because the foreign body, although it was metallic, was being used as a toothpick.

PRINCIPLES GOVERNING TOTAL GASTRECTOMY

A Report of Forty-One Cases

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AND

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IN THE progressive evolution of the scope of subtotal gastrectomy for cancer of the stomach, total gastrectomy has become a necessity in the armamentarium of the abdominal surgeon. From the operation of pylorectomy by Billroth in 1881 to total gastrectomy the entire history of modern surgical technic has developed, and yet the philosophy and approach to the more extensive procedures seem little changed in Lahey's¹ analysis of the problem in 1938 "the operation is to be considered only in those cases in which a large part of the stomach is involved, extragastric metastases, even though they are not visible, and the operation is not justifiable if they are visible, are present in practically all of the cases. In those cases in which the malignant lesion in the stomach is carcinoma, one cannot reasonably expect to be able to accomplish anything more than a prolongation of life but that with reasonable digestive comfort."

The operative technic has immeasurably improved in sixty-five years but the pessimistic and futile point of view has remained unchanged. This does not imply that the operation is advocated solely for palliation for the risks are too great, but in the face of definite indications, the handicaps and hazards must be accepted if progress is to be made in increasing the resectability of this most common and insidious cancer.

The key of the problem may be succinctly expressed by a paraphrase of Graham's² statement of attitude. The enthusiasm which the indi-

Aided by a grant from Mr and Mrs T Ferdinand Wilcox

From the Gastric Service of the Memorial Hospital for Cancer and Allied Diseases

1 Lahey, F H Complete Removal of the Stomach for Malignancy with Report of Five Surgically Successful Cases, *Surg, Gynec. & Obst.* 67:213-223, 1938

2 Graham, R R Total Gastrectomy for Carcinoma of the Stomach, *Arch Surg.* 46:907-917 (June) 1943

vidual surgeon displays for this operative procedure will depend largely on his philosophy of life. If such philosophy demands that all efforts be used to prolong life, even though the effort be accomplished by grave immediate risk, and though the patient ultimately must die from carcinoma, providing he lives long enough, then such a surgeon must be an advocate of total gastrectomy.

We may say that though the purpose of the operation is curative, the result may be only palliative.

Kronlein³ conceived the term of total gastrectomy as most definitive of the operation for gastric cancer, and stated that it included "only those in which both the pylorus and the cardia had been removed, and on which examination showed a portion of the esophagus at one end and the duodenum at the other end". He stated that the cardiac and pyloric sphincters should be removed. In 2 instances of subtotal gastrectomy in our series, the pathologist observed esophageal squamous epithelium and duodenal mucosa, but the operations have not been listed as total gastrectomies. The explanation of this paradox lies in the complete removal of the lesser gastric curvature and utilization of the fundus for the gastrojejunral anastomosis.

The historical development has been detailed in the collective review by one of us (G T P)⁴ of the literature up to July 1942, and report of the first 20 cases. Since the first known total gastrectomy in man, done by Conner,⁵ of Cincinnati, in 1884, and the first successful one, by Schlatter,⁶ of Switzerland, in 1897, the operation has been more enthusiastically extended, so that recent reports reveal gradually declining mortality rates and an increasing number of three and five year survivals.

PRINCIPLE OF TOTAL GASTRECTOMY

If an organ is unessential for life, the growing concept of cancer therapy more and more suggests the sacrifice of the entire organ, the regional lymph nodes which drain it and the intervening lymphatics. We do not advocate a discontinuance of subtotal gastrectomy as yet because in our experience the deaths which have followed this more

3 Kronlein Ueber die bisherigen Erfahrungen bei der radikalen Operation des Magencarcinoms (der Magenresektion und der Magenexstirpation) an der Zürcher chirurgischen Klinik, Verhandl d deutsch Gesellsch f Chir (pt. 2) 27 49-51 and 184-188, 1898

4 Pack, G T, and McNeer, G Total Gastrectomy for Cancer A Collective Review of the Literature and an Original Report of Twenty Cases, Surg, Gynec & Obst 77 265-299, 1943

5 Conner, P S Report of a Case of Complete Resection of the Stomach, M News 45 578, 1884

6 Schlatter, C Ueber Ernährung und Verdauung nach vollständiger Entfernung des Magens Oesophagoenterostomie beim Menschen, Beitr z klin Chir 19 757-776, 1897

conservative operation have been due to metastases and not to local recurrence in the retained gastric segment.

The removal of the stomach and tributary lymph nodes en bloc is the ideal operation for gastric cancer and is the only technic which embodies the philosophy for excisions of mammary, colonic or rectal carcinoma of epithelial carcinoma of the skin and appendages and of melanoma. The well planned total gastrectomy is both an excision of the entire stomach and dissection en masse of the related lymph nodes. The operation is designed to include the greater omentum, the lymphatics and nodes along the greater curvature, the nodes of the left gastropancreatic fold, the juxtagastric nodes, the right gastroepiploic nodes, the intrapyloric and the retrohypopyloric nodes, the lymph nodes of the lesser curvature, the gastrohepatic omentum, the nodes along the celiac axis and the nodes in the gastrosplenic ligament, and, if they cannot be separated from the spleen or if there is local extension into the spleen, the spleen itself is included in the en bloc dissection. It may even be feasible to include the peritoneum of the entire lesser sac in the dissection.

DISTRIBUTION OF CASES

Thirty-seven stomachs were resected for carcinoma, and 1 for an extensive reticulum cell sarcoma. Of the three lesions which proved to be benign, one was noncancerous *linitis plastica* probably on a syphilitic basis, and two were large benign ulcers high on the lesser curvature.

In this group of patients undergoing total gastrectomy 12 were women and 29 were men. The average age for the women was 53 years and 10 months, and for the men, 54 years and 7 months, with an over-all average for the 41 patients of 54 years and 5 months. In the 37 cases in which resection was done for gastric cancer 26 patients were men averaging 55 years and 9 months of age, and 11 of the patients were women, the average age being 55 years and 5 months, with an over-all average for the 37 patients of 55 years and 8 months. The youngest person in our series for whom total gastrectomy was done was a 30 year old Chinese man. The oldest was a 79 year old white man.

SIGNS AND SYMPTOMS

Pain has been the initial complaint of 20 patients. There is nothing characteristic of this particular distress, because in some it was relieved by food, while in others it was constant and nothing afforded relief (table 1). A few complained only of vague discomfort. Anorexia was the presenting complaint of 5 and weakness of 4. Indigestion was found

7 The patient of Lieut Col Willis M Weeden Medical Corp 141 Regtation Hospital Army of the United States

in 3, vomiting, belching and dysphagia in 2 each, and nausea, loss of weight and rapid satiation were the original complaints in 1 each. The history itself was never indicative of the type of procedure which would be necessary, and only roentgen and gastroscopic examination gave a clue as to the extensive operation demanded. As was found in the collective review of 162 patients for whom information was available, 75 per cent had symptoms of less than one year, and it was shown that the average duration of symptoms was eleven and seven-tenths months, as opposed to sixteen months in the series of patients for whom subtotal gastrectomy was indicated. In this group 29 of the 41 patients, or 75.6 per cent, presented symptoms of one year or less. The average duration of symptoms was eleven and seven-tenths months.

INDICATIONS FOR TOTAL GASTRECTOMY

1. *Location*.—The first and most important indication is the location and the extension of the disease found at laparotomy. If the tumor

TABLE 1.—*Initial Symptoms of Patients Operated On for Total Gastrectomy*

Total cases	- 41
Pain	20
Anorexia	5
Weakness	4
"Indigestion"	3
Vomiting	2
Belching	2
Dysphagia	2
Nausea	1
Loss of weight	1
Rapid satiation	1

Average duration of symptoms 11.7 months
Symptoms of one year or less 29, or 75.6 per cent

has extended to the cardiac lymph nodes from an original lesion in the pylorus, subtotal gastric resection is of no avail and total gastrectomy is the only feasible operation. This indication perhaps resolves itself to the fact that any tumor which cannot be completely removed by subtotal resection demands total gastrectomy (fig 1). Postmortem examinations of subjects dying of untreated gastric cancer in reported series from the time of William Welch to the monographic report by Livingston and Pack⁸ show a constant figure of 20 to 25 per cent of these patients with the cancer confined to the stomach without even demonstrable microscopic evidence of metastasis. Contraindication to operation in this group is perhaps the debility or poor physical condition of the patient, not age alone, as we have performed a total gastrectomy in a 79 year old subject.

⁸ Livingston, E. M., and Pack, G. T. End-Results in the Treatment of Gastric Cancer, New York, Paul B. Hoeber, Inc., 1939.

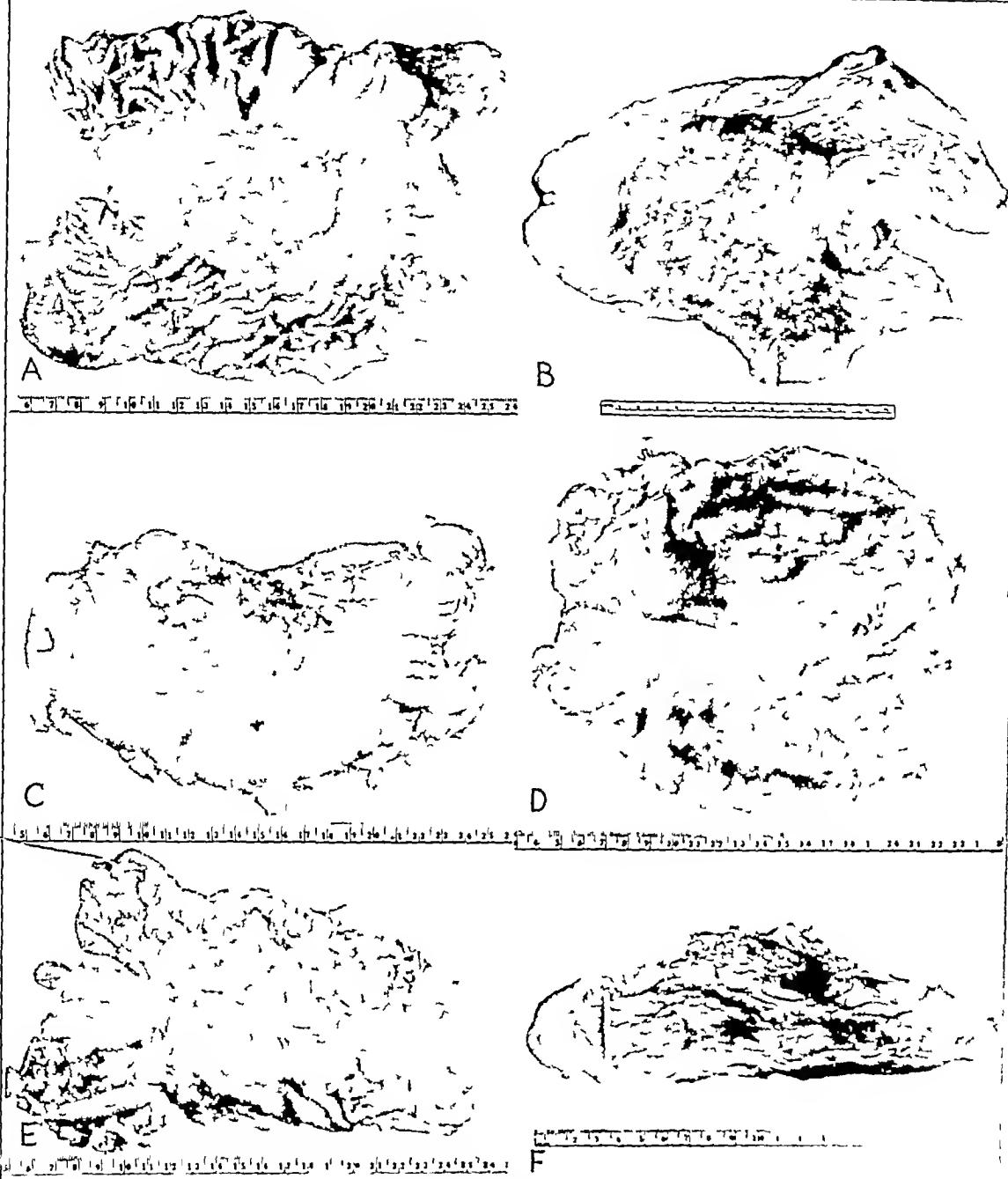


Fig 1.—Specimens of total resection of the stomach. *A* (patient A G), photograph of gastric cancer arising along the lesser curvature showing an ulcerated tumor mass, the submucosal extension of the lesion is within 1 cm of the margin of the cardia. *B* (patient I G) specimen is opened along greater curvature and shows a large polypoid mass occupying almost all of the lesser curvature. *C* (patient M L), specimen before opening which shows infiltration of lesion into the lesser omentum. *D* (patient M L) specimen has been opened along the greater curvature and shows involvement of the greater portion of the stomach and cardia to within 3 cm of the pylorus. The entire mucosa is hypertrophied and congested. *E* (patient H M), primary operable reticulum cell lymphoma of the stomach. A large shallow ulcer occupies almost two-thirds of the greater curvature wall along the greater curvature. *F* (patient D S) diffuse limit plate carcinoma with the thickening of the submucosal layer and the intact mucosa.

In surgically resected total stomachs, the incidence of nodal metastases has varied in different clinics. Graham (Toronto General Hospital) reported 67 per cent, Lahey (Lahey Clinic) 87 per cent, Waugh and Fahlund (Mayo Clinic), 72 per cent, we (Memorial Hospital for Cancer and Allied Diseases) have encountered 62 per cent. Of course this cannot be construed to mean that local extension in itself is sufficient cause for assuming the added risk of the radical procedure. Finney and Rienhoff,⁹ in analyzing the cases reported as total gastrectomies, showed that in removing the last 3 inches (7.6 cm) of stomach left at the cardia the operative risk was much greater—53.8 per cent of 67 cases of authentic total resections—but in those in which less than 3 cm was left at the cardiac or pyloric end, or both, 75 per cent of the 55 patients recovered, the mortality rate for the complete procedure being more than twice as great as for the radical subtotal gastrectomy. It therefore appears that when the local extent of the disease demands

TABLE 2—*Total Gastrectomy—Location of the Lesion*

Location	Number	Percentage
Total	41	100.0
Proximal portion of the stomach—total	25	61.0
Cardia only	4	
Cardia with extension to the esophagus	1	
Lesser curvature and cardia	1	
Proximal one third	2	
Proximal one half	8	
Proximal two thirds	3	
Lesser curvature from pylorus to cardia	6	
Midportion of the stomach	7	17.1
Almost entire or entire stomach	9	21.9

greater effort on the part of the surgeon, the patient must also be capable of presenting greater resistance to the more formidable procedure if the operative mortality does not increase.

The accompanying table shows that in 61 per cent of our patients the cancers were situated in the proximal two thirds of the stomach and that in only 22 per cent was the entire stomach involved, indicative of the fact that these patients could not be afforded any hope by any operation short of total gastrectomy (table 2).

By encompassing lesions of greater extent and unfavorable locality, a greater resectability rate will result in greater numbers of three year survivals. In 1940 Abrahamson and Hinton,¹⁰ in reviewing 444 cases of gastric carcinoma, found that 74, or 28 per cent, were located unfavorably for radical resection and that 135 cases showed roentgenologic evidence of carcinoma involving more than a single portion of the stomach,

9 Finney, J. M. T., and Rienhoff, W. F., Jr. Gastrectomy, Arch Surg 18:140-162 (Jan., pt. 1) 1929.

10 Abrahamson, R. H., and Hinton, J. W. Carcinoma of the Stomach, Surg., Gynec & Obst. 71:135-141, 1940.

and hence were unfavorable because of the extent of the lesion. While the 12 cases in their group 1, those showing involvement of the esophagus by extension, would necessitate transthoracic, transdiaphragmatic cardietomy or total gastrectomy, the remainder might admit of salvage by complete gastrectomy despite the marked intragastric extension of the disease.

It has seemed to us that in extending the scope of the operation for gastric cancer, total gastrectomy offers the greatest opportunity to salvage more patients with this disease. From 1916 through 1945 there were 1,117 patients with carcinoma of the stomach cared for at the Memorial Hospital, of which number 759 underwent operation. A total of two hundred and twenty-seven resections have been performed, or in 20.3 per cent of those operated on but if total gastrectomy had not been done, only 191 stomachs would have been resected, or 17.9 per cent, a difference of 2.4 per cent. The salvage rate would be 24 per thousand less the anticipated mortality of 31.7 per cent. This figure obtained by merely increasing the scope of the procedure seems far more gratifying than the salvage rate obtained even by mass surveys of asymptomatic patients of cancer age as conducted by St. John Swenson and Harvey.¹¹ They found a rate of 1.24 per thousand cases of patients over 50 years of age in the surgical outpatient clinic by conducting a routine gastrointestinal roentgenologic survey. By use of both transthoracic cardietomy and total gastrectomy and abdominal total gastrectomy, a salvage rate of 60 patients per thousand cases has been effected in our series at the Memorial Hospital. This seems to indicate the most favorable and efficient means of improving the outlook for cancer of the stomach that is available today.

2 *Linitis plastica*—*Linitis plastica* because of its slow growth with complete involvement of the stomach and often without metastases is always an indication for the radical procedure (fig. 2A). This diagnosis was made four times in this present series, 1 instance was an inflammatory type of linitis, possibly of syphilitic origin.

3 *Lymphosarcoma*—*Lymphosarcoma*, inasmuch as it sometimes is a diffuse infiltrating neoplasm which is often not distinguished preoperatively from carcinoma of the stomach, occasionally requires total resection. Of course with this diagnosis postoperative roentgen therapy is definitely indicated as a prophylactic measure. Diffuse infiltrating sarcomas of the stomach are almost always lymphosarcoma and grow so rapidly that they sometimes do not seem amenable to surgical therapy. This type of lesion however, when no extraintestinal

¹¹ St. John F. B., Swenson P. C. and Harvey H. D. An Experience with the Early Diagnosis of Gastric Carcinoma. Ann. Surg. 119: 225-241, 1944.

extension can be demonstrated, demands exploration to determine the feasibility of total gastrectomy

4 *Malignant Leiomyoma or Leiomyosarcoma*—Malignant leiomyoma or leiomyosarcoma is another tumor which may require total gastrectomy because the lesion grows rapidly and attains large size, but this tumor is usually well circumscribed and easily extirpated

5 *Multiple Polyposis, Diffuse Polyposis en Nappe or Polyposis Gastritis*—Multiple polyposis, diffuse polyposis *en nappe* or polyposis gastritis may occasionally justify a radical resection, depending on the extent of the disease. If any involved part of the stomach is allowed to remain in these cases, the danger from hemorrhage or development of cancer may be as great as if a subtotal resection were not done

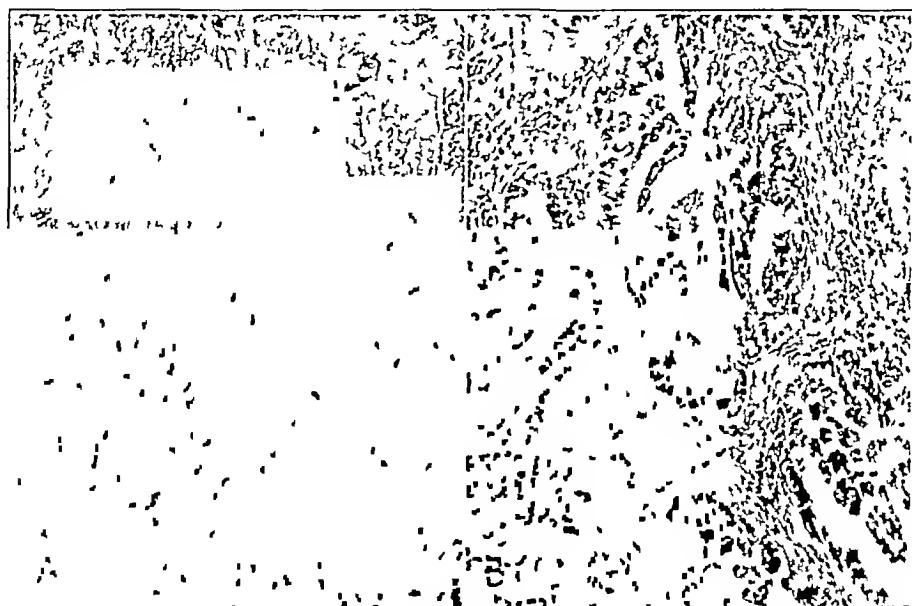
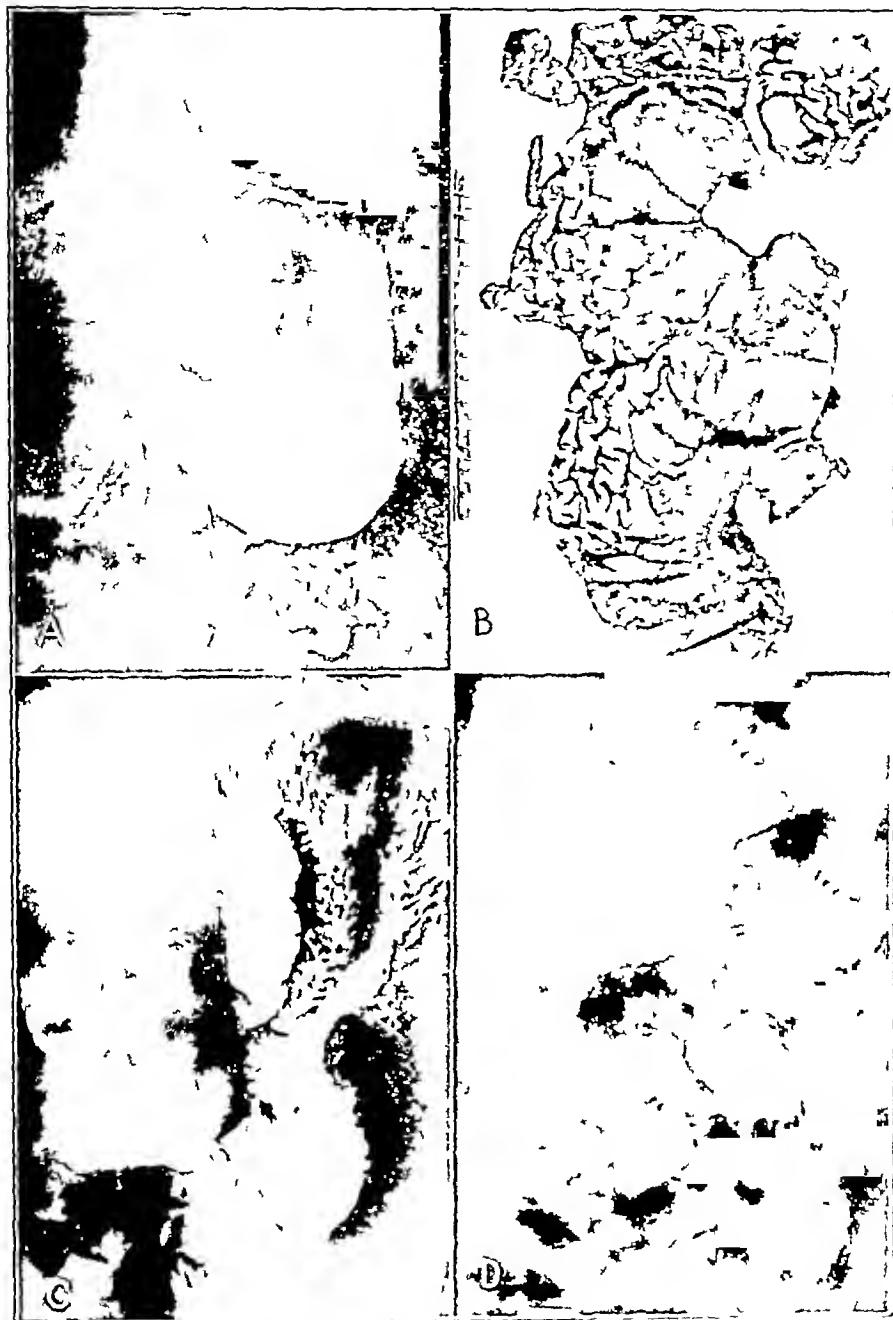


Fig 2—*A* (patient D S), photomicrograph through muscular wall of the stomach involved by limitis plastica, showing the diffuse extension of the tumor process between muscle bundles \times approximately 185 (The gross specimen is shown in fig 1F) *B* (patient G W), photomicrograph of specimen of fungating tumor showing an adenoma malignum, grade II. This tumor extended to less than 1 cm from the line of resection (a roentgenogram of the patient is shown in fig 4A). The patient was living without evidence of recurrence when last examined, forty-three months after operation \times approximately 185

6 *Gastric Ulcer High on the Lesser Curvature*—Gastric ulcer high on the lesser curvature, which even after exploration appears to be carcinomatous, may demand total gastrectomy on the clinical assumption of its malignancy. In a patient of our series, the ulcer was thought to be carcinomatous but proved to be a benign peptic ulcer high on the lesser curvature. Another gastric ulcer, properly diagnosed as benign



before operation, required total gastrectomy to remove the adjacent inflamed stomach wall (fig 3) Jones and Kehm¹² reported that in their 10 patients, 2 were subjected to this radical procedure because of penetrating ulcers high in the cardia which were intractable under medical management, while five of the seventy-seven total gastrectomies in the Mayo Clinic series were performed for benign ulcers, which were impossible to tell from malignant ulcers¹³ Abdominal cardiectomy or resection of the proximal half or more of the stomach with a subdiaphragmatic esophagogastostomy is sometimes feasible We have done this on a few occasions, the variety of subtotal gastrectomy would seem preferable to total gastrectomy, especially in the case of benign lesions

Certain technical indications must obtain 1 The lesion must be confined to the stomach, tributary nodes and immediate perigastric tissues, and no distant metastases should be present 2 There must be sufficient mobile esophagus above the lesion to allow at least 3 cm of clear margin beyond the apparent limit of involvement and enough added esophagus for the anastomosis after this resection We concur with de Amesti¹⁴ who quotes Verbruggen's work which shows intramural extension 3 to 4 cm beyond the gross limits of the tumor in 40 operative specimens Accordingly, he believes that there should be at least 3 cm of free margin above the resection One of our patients, in whom the pathologist reported submucosal extension of a grade III gelatinous cancer at the line of esophageal section, lived two years following trans-thoracic total gastrectomy Another patient with an adenoma malignum, grade II, which extended to less than 1 cm from the line of resection, was alive without evidence of recurrence when last examined, forty-three months after operation (fig 2 B) 3 Although the incidence in which involvement does not extend beyond the stomach into the perigastric lymph nodes varies from 13 to 38 per cent in different groups, it does not follow that this alone determines resectability, because the patient must be at least a fair operative risk to withstand the procedure

ROENTGENOGRAPHY AND GASTROSCOPY

Fluoroscopic examination of the stomach is perhaps the most important and easiest means of determining the extent of invasion of the tumor, because submucosal involvement of the cardia or pylorus may be revealed by alteration of motility and rugal pattern that is not apparent

12 Jones, T E, and Kehm, R W Total Gastrectomy, Surg, Gynec & Obst
80 534-538, 1945

13 Waugh, J M, and Fahlund, G T R Total Gastrectomy, S Clin North America 25 903-917, 1945

14 de Amesti, F Total Gastrectomy for Cancer, Ann Surg 117 183-190, 1943

on roentgenograms. Roentgenologic examination usually reveals the extent and type of the lesion (fig 4), but esophagoscopy may be necessary to determine the upward involvement of the cardia and esophagus. If esophagoscopy shows extension beyond the stomach, then transthoracic



and not abdominal, exploration is in order. If roentgenologic studies show freedom of the cardia, the type of lesion can be determined with the flexible gastroscope.

PREOPERATIVE CARE

These patients are hospitalized at least five days before operation for complete evaluation of their physical status. Medical consultation determines whether the patient's cardiovascular system will tolerate the risk. A low residue, high protein diet is forced, if possible, and if it is not tolerated, the same nutrition is incorporated in a liquid diet. The red cell count and hemoglobin level are restored with transfusions, as well as depleted serum protein. Hard candies and fortified fruit juices are forced to replenish depleted hepatic glycogen stores and to mobilize hepatic lipids. Daily—and, if there is any obstruction, twice daily—gastric aspiration and lavage with tenth normal hydrochloric acid are performed to reduce the bacterial count of the pathogenic organisms uniformly present in this type of case. The patients are sent to the operating room with an indwelling nasal Levine tube.

ANESTHESIA

The anesthesia of choice in this entire series, except for transthoracic, transdiaphragmatic total gastric resection has been continuous spinal anesthesia. It has been attended by uniformly good relaxation in a difficult approach. A 2.5 per cent solution of pentothal sodium has been given intravenously for restlessness and apprehension. One operation of transthoracic total gastrectomy was done with the patient under ether and nitrous oxide-oxygen anesthesia with controlled breathing. We have not used local and splanchnic block as de Amesti¹⁴ and McCorkle and Silvani¹⁵ advocated. Our series contrasts with Waugh and Fahlund's¹³ series in which intratracheally administered ether was the agent of preference and in which group spinal anesthesia was not used. Spinal anesthesia has not increased the tendency to shock, as some authors believe it does, nor has it been too effective in warding off pulmonary complications, as we had previously believed.

OPERATIVE TECHNIC

In only 1 patient has a transthoracic transdiaphragmatic total gastrectomy been done. If the preoperative roentgenographic and gastroscopic studies indicate the necessity for total gastrectomy and if the distal esophagus is not involved the transabdominal approach is preferred. The transthoracic approach is considered the one of choice if

¹⁵ McCorkle, H. J., and Silvani, H. L. The Technique of Total Gastrectomy with Particular Reference to the Use of Local Anesthesia, *S. Clin. North America* **23** 1465-1475, 1943.

there is esophageal obstruction, whether the tumor is primary in the stomach or the esophagus.

In these forty-one total gastric resections, gastrointestinal continuity was established by esophagojejunostomy in all except 1 case, in which esophagoduodenostomy was done. The greater ease with which the esophagus is anastomosed to the jejunum, as opposed to the tension under which esophagoduodenostomy is effected, has caused us to abandon the latter procedure entirely. A mortality rate of 40.7 per cent in the collected reports in which esophagoduodenostomy was performed as opposed to 33.9 per cent of the collected cases of esophagojejunostomy indicates a definite superiority of the latter technic.

A midline incision in the upper part of the abdomen has been the approach of choice, with the lower pole of the incision veering just to the left of the umbilicus if any more exposure is necessary, though a left paramedian incision has been used in about an equal number of cases. A routine abdominal exploration precedes the decision of resectability. A definite routine of exploration must show freedom of extension in seven regions. 1 By palpating through the foramen of Winslow the hepatoduodenal ligament is palpated for evidence of extension or infiltration of the cancer toward the portal fissure. 2 The gastrohepatic ligament is broken through to ascertain whether lymphatic extension around the celiac axis precludes resection. If there is sufficient margin to allow even a close division of the origin from the celiac axis, the celiac lymph nodes and the origin of the left gastric artery can be readily stripped off together. 3 The spleen is visualized to determine the extension of the cancer into the gastrosplenic ligament and to determine whether splenectomy will be necessary in order to excise the lesion en bloc. 4 The abdominal part of esophagus is palpated to determine its mobility and the extension of the cancer past the cardia and to estimate whether there will be sufficient length of esophagus after mobilization to effect an anastomosis. 5 Then the posterior wall of the stomach is inspected to detect any possible extension into the peripancreatic capsule. 6 The superior surface of the transverse mesocolon is examined to ascertain freedom from invasion of the middle colic vessels. 7 Finally, the cul-de-sac is palpated to determine the presence of cancer deposits.

After these maneuvers it still may be impossible to determine the resectability of the stomach, and the operator may have to proceed in mobilizing the stomach to determine this fact. Until the duodenum is transected, an irreversible decision for proceeding with the operation does not have to be made because of the extreme vascularity of the stomach and its remarkable viability even after three of its four major

the retropancreaticoduodenal node, the left gastroepiploic nodes and any nodes along the gastrosplenic ligament. If there is extensive invasion of the ligament it may be necessary to include the spleen in the dissection, though we do not employ this as a routine procedure.

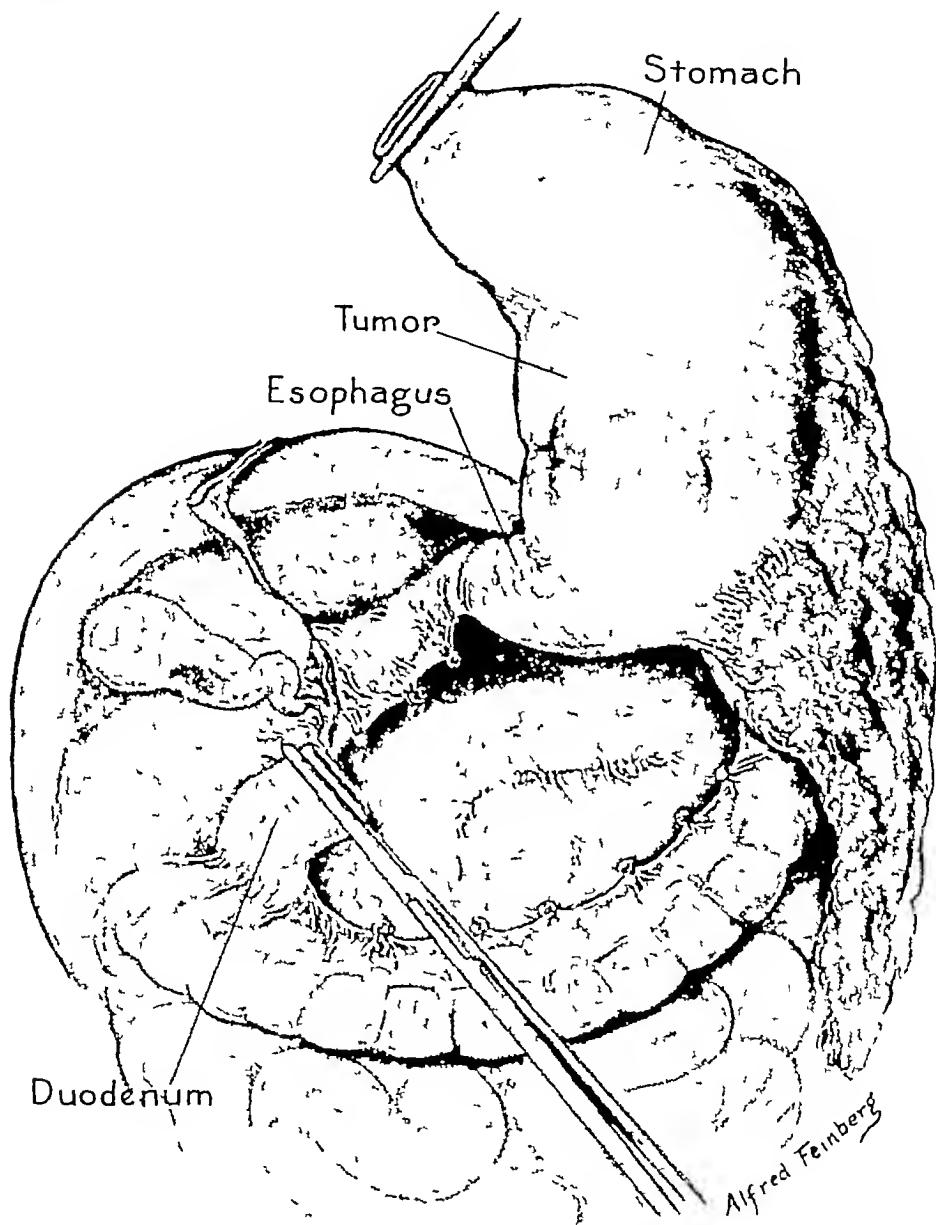
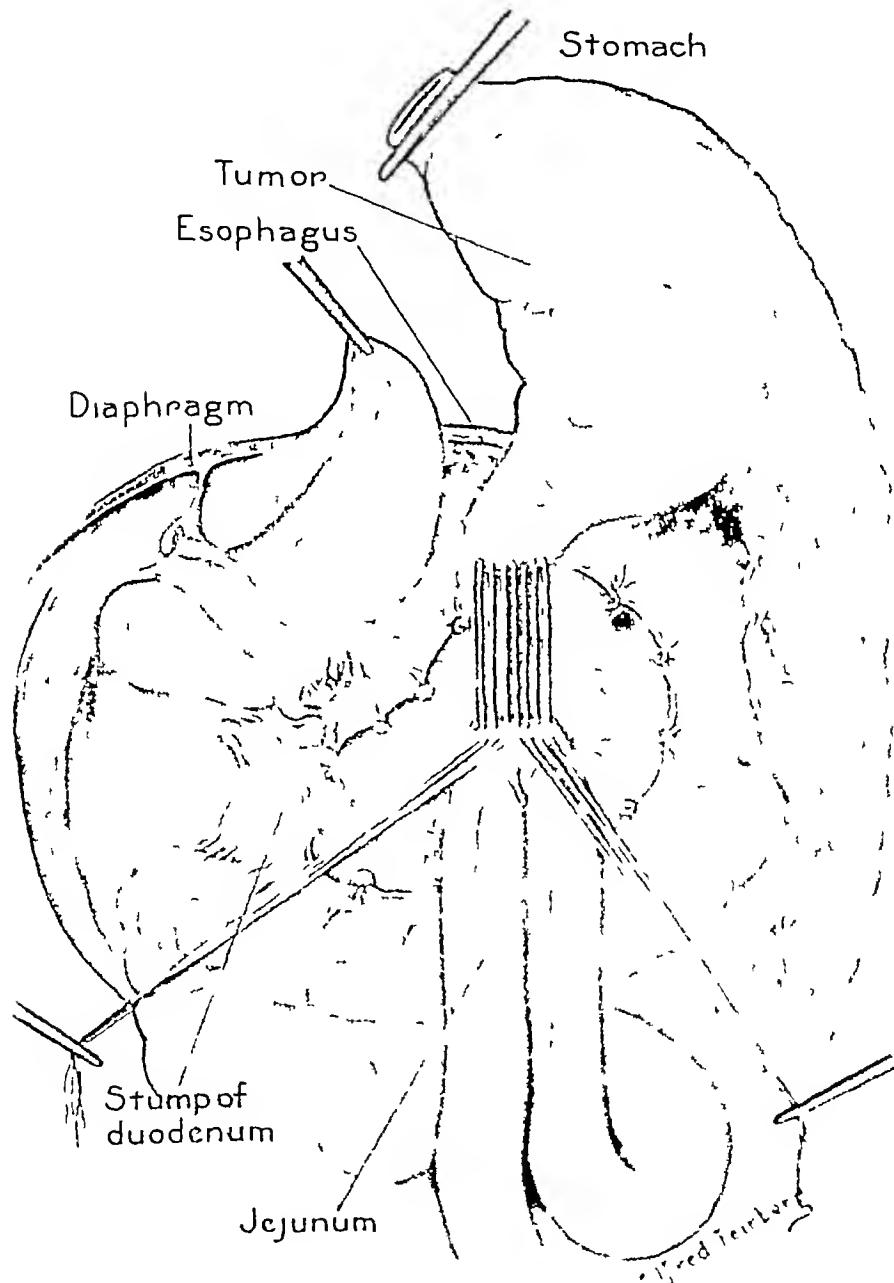


Fig 5.—Technic of total gastrectomy. The duodenum has been transected after ligating the right gastric, the gastroduodenal and the right gastroepiploic vessels and after resecting the omentum along the reflection over the transverse colon.

When resectability has been established, the duodenum is mobilized and transected after ligation of the right gastric, the gastroduodenal and right gastro-

epiploic arteries and veins (fig 5). Our choice of closure of the duodenal stump has been the Parker-Kerr basting stitch technic reinforced with silk Lembert sutures, although the DePetz mechanism has been used in place of the basting stitch closure in a few instances. The peripancreatic capsule is sutured over the



stump. The open pyloric segment is carefully wrapped with a dry laparotomy pad to avoid contamination and the cardia is then mobilized. The short gastric arteries are ligated, after freeing of the gastrolienal ligament, and, with the mobility thus afforded, the left gastric vessels can be easily approached, clamped, cut and

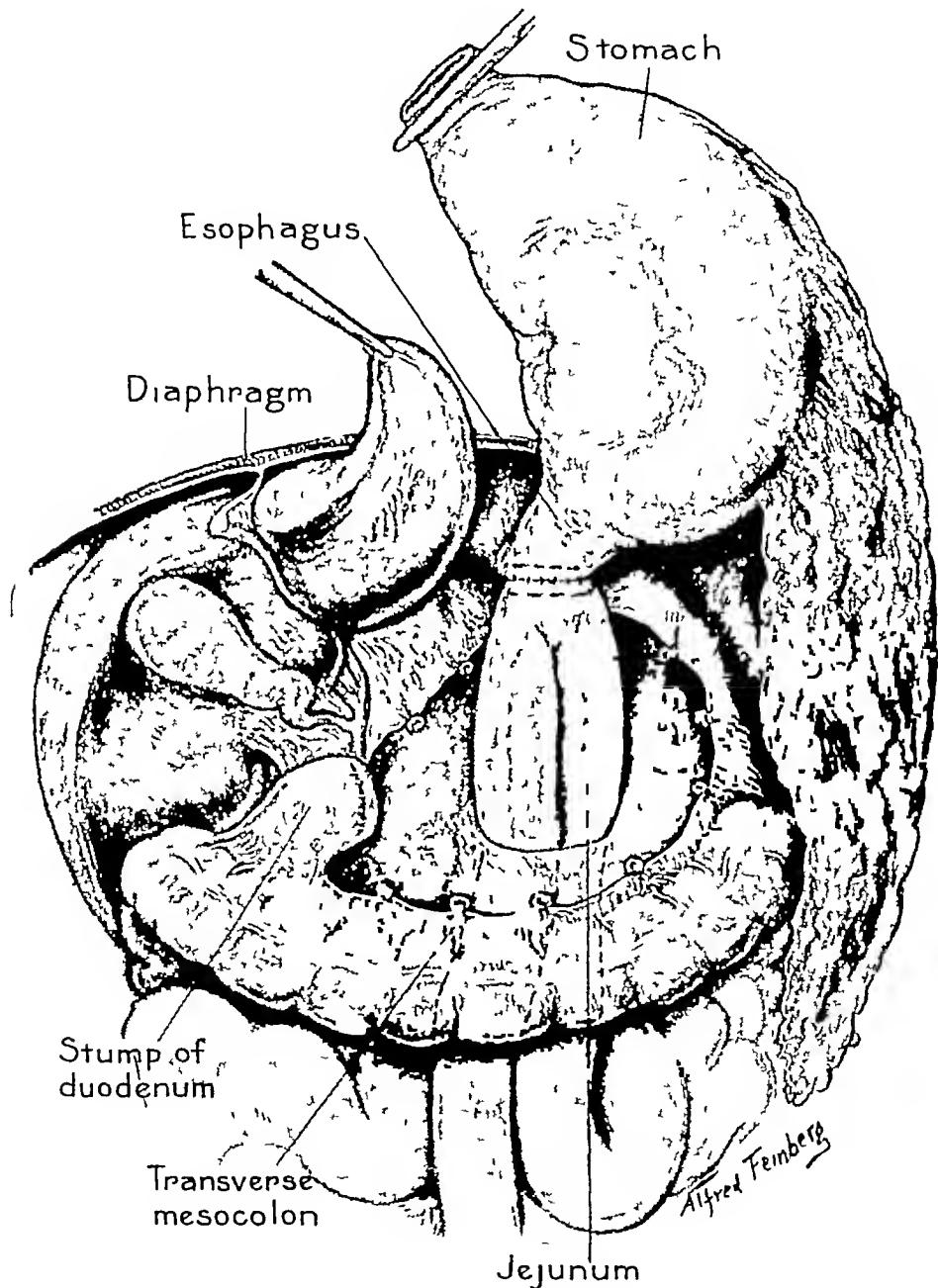


Fig 7.—Technic of total gastrectomy, showing retrocolic type of anastomosis. The lines of incision into the esophagus and jejunum are shown.

ligated with a suture ligature. The left triangular ligament of the liver is severed so that the left lobe of the liver can be retracted medially to afford a better

exposure of the esophagus. At this time peritoneal flaps are prepared from the diaphragm, both anteriorly and posteriorly to the esophagus, then by blunt digital dissection the esophagus is mobilized through the hiatus of the diaphragm so that up to 5 cm more esophagus can be brought through the diaphragm to aid in making the anastomosis and relaxing the tension on it.

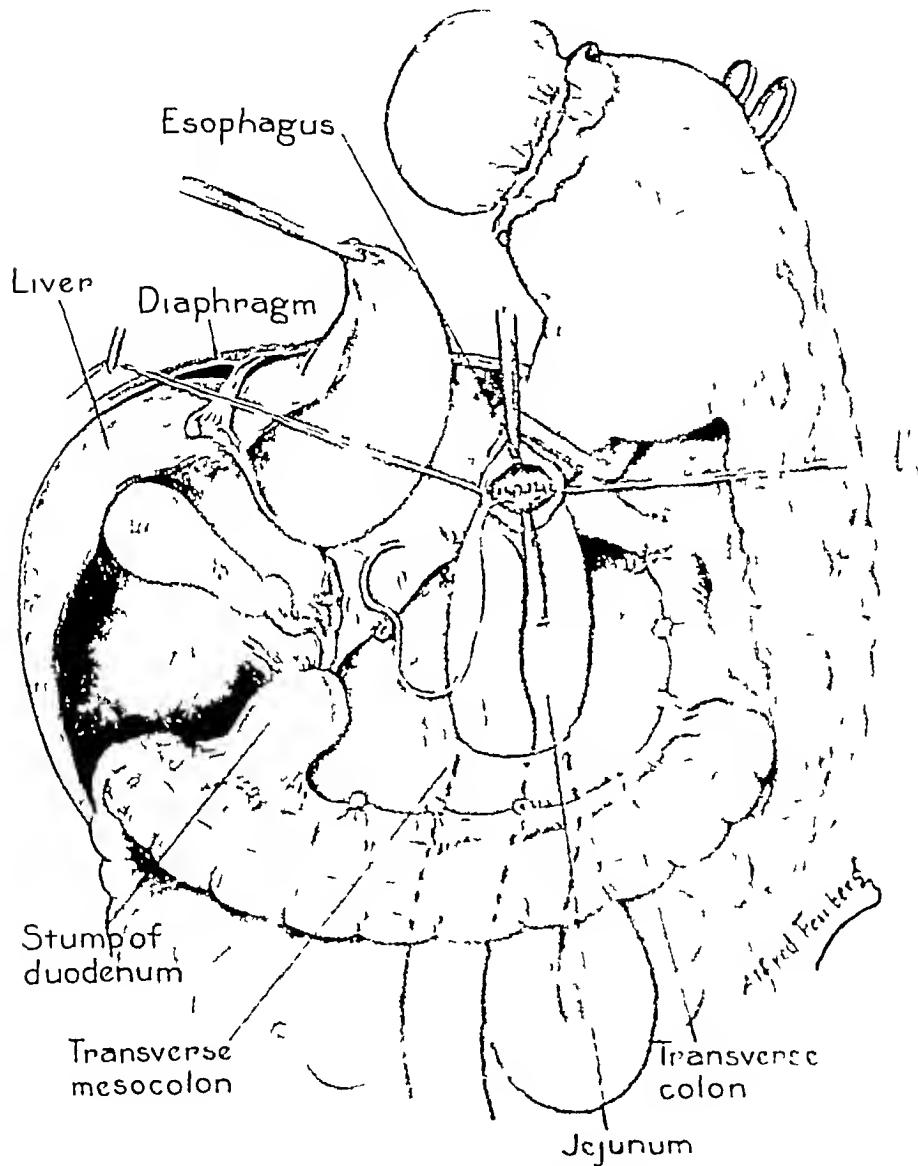


Fig 8.—Technic of total gastrectomy. A right angle tube is placed over the reflux of gastric contents into esophagus. The third layer of pectoral muscle is in place.

jejunal loop is created of at least 10 to 15 inches (25.4 to 38.1 cm) in length. We do not believe in first affixing the jejunum to the diaphragm before creating the anastomosis because we have found it much easier to place the posterior seromuscular-muscular layer of interrupted silk mattress sutures with the jejunum at some distance from the esophagus (fig 6). After the sutures have been placed, with the attendant good visibility, the jejunum can be slid up to its proper position.

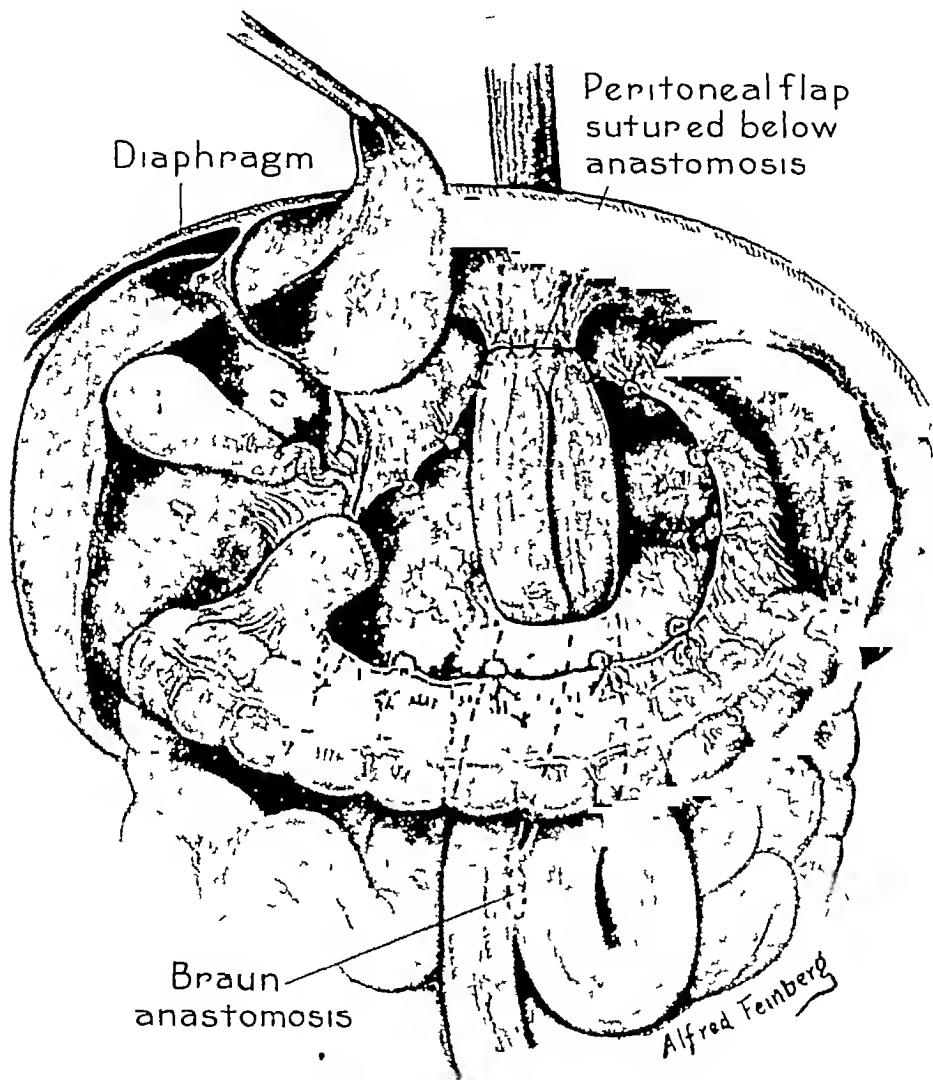


Fig 9.—Technic of total gastrectomy. The peritoneal flap is sutured below the line of the anastomosis and the lateral jejunoojejunostomy has been completed.

and the sutures tied. Incisions in both esophagus and jejunum are then made (fig 7) down to the mucosa and a posterior layer of fine chromicized surgical gut is placed and tied. A continuous mucosal suture of surgical gut is inserted before the specimen is resected (fig 8), the suture is locked, to avoid purse-string constriction of the stoma, before the anterior layer is introduced as a Connell running suture. The remaining anterior layer of silk sutures is placed and the

diaphragmatic flaps then sutured onto a lower level of the jejunum (fig 9). Tension on the suture line is relieved by suturing the afferent and efferent loops to the diaphragm lateral to the anastomosis.

We now routinely use an indwelling Levine tube to place the anastomosis at complete rest, and at this stage of the operation the anesthetist advances the tube so that the operator can guide it into the distal lumen of the jejunum for a distance of 12 to 16 inches (30.5 to 40.6 cm) for orojejunal feeding purposes.

In all except 5 of our 41 cases we have performed a jejunomejunoostomy, an incidence of 87.8 per cent. While Lahey has abandoned this procedure entirely, it was used in 46 of the 77 cases of Waugh and Fahlund.¹³ With the Roscoe Graham technic the supplementary enteroenterostomy or Braun anastomosis is a necessity. It is of great advantage to have the bile and pancreatic juices in the proximal limb pass through the anastomosis into the distal loop. It also would appear that this relieves pressure on the duodenal stump in the immediate post-operative period.

Two Penrose drains are placed the ends of each on either side of the anastomosis and brought out through the superior pole of the incision, 5 to 10 gm of powdered sulfanilamide is sprinkled along the line of anastomosis and over the duodenal stump. The peritoneum is closed with a continuous suture of chromicized surgical gut and the fascia is repaired with interrupted sutures of fine black silk and vertical mattress sutures of black silk to the skin. Because patients with gastric cancer have been more prone to wound disruption and in collected series of wound disruptions¹⁴ head all other groups in incidence of wound dehiscence figure or eight braided silk retention sutures are routinely used and are not removed until the fourteenth postoperative day. No case of evisceration has occurred in this series.

At the end of the operation if the patient's condition permits curcumin (isoamylhydrocuprene) in oil is injected into the sixth to the eleventh intercostal nerves along the posterior axillary line 3 cc for each nerve the procedure being done on both sides if the midline incision is used. If this procedure is done the vital capacity is not impaired and pulmonary complications are less apt to occur.

POSTOPERATIVE CARE

If the patient is in shock at the conclusion of his operation he is sent directly to his bed in the operating room so that unnecessary handling will not aggravate the condition. Blood transfusions have been used liberally with at least one to two 500 cc transfusions, even up to four being given during the operation in order to forestall shock. Blood or plasma and the Trendelenburg position are continued until the blood pressure and pulse are stabilized. Subsequent fluid replacement is given with due respect to blood cell count and total serum protein determined at two day intervals.

forced respiration, change of position at least every two hours and sitting-up posture in bed are routine to encourage adequate respiratory excursion. Tracheal suction with catheter or bronchoscopic aspiration is used as soon as the patient fails to raise the bronchial secretion himself. Formerly sulfonamide drugs were routinely used without appreciable prophylactic benefit. Now penicillin, both intramuscularly and, more recently, as aerosol inhalations, has been used prophylactically, but there have not been enough patients in this time to evaluate its efficacy in preventing pulmonary complications.

The patient is forced to dorsiflex his feet and to move his legs to encourage the femoral circulation and to prevent postoperative thrombophlebitis. Pulmonary embolic accidents have not occurred in this series. Unless some unusual contraindication exists, the patient is out of bed and ambulatory within forty-eight hours.

Three ounce (89 cc) feedings of albumin water are given through the indwelling Levine tube three hours after the patient returns from the operating room and, thereafter, at three hour intervals for the day of the operation. Feedings are gradually increased from 1,280 calories on the first postoperative day, by giving alternate 4 ounce (118 cc) feedings of albumin water and peptonized milk, up to 3,000 calories on the ninth day, by a special formula. This contains 118 Gm of protein on the last day of feeding, so that this most essential element of post-operative alimentation is not slighted. Fluids given parenterally are also necessary the first three or four days. Supplemental polyvitamin therapy is given in the tube, with especial attention to vitamin B complex, to ward off gastrointestinal hypomotility.

Jejunostomy has been used in 16 cases, but more recently we have not used it. Jejunostomy is done in the efferent limb, distal to the Braun anastomosis. Several of our patients in whom the Levine tube was not sutured in the nose have pulled the indwelling tube out so that it was necessary to start them on oral feedings, which we have never hesitated to do so far as we lack no confidence in the security of the anastomosis. Yet it has never been possible to give the adequate alimentation which these patients demand, for despite intensive preparation to restore protein balance, adequate protein reserves for the early restricted post-operative course of at least ten days cannot be established in the preoperative management. Maintaining high protein, as well as caloric, intake has been the prime consideration in favoring an indwelling Levine tube for ten days postoperatively, though we also feel that enforcing physiologic rest at the site of the anastomosis is almost equally important.

In Waugh and Fahlund's series of 77 cases, postoperative nutrition was maintained by a jejunostomy tube in 54.5 per cent and by a nasal tube passing to the distal lumen of the jejunum in 27.3 per cent of the cases, while in 18.2 per cent no method of tube feeding was used. As they compared these three groups they felt that the hospital survival rate was roughly the same except that the slightly lower survival rate in the patients having jejunostomies could be attributed to the fact that this procedure was used in patients who were poorer risks.

Analysis of our series has revealed a significant factor which may overshadow the advantage of maintaining protein balance with an orogastric Levine tube. In the 16 cases in which a jejunostomy has been done, there were four operative deaths, only one of which was due directly to a pulmonary complication, while among the 25 patients who had Levine tube feedings there were five deaths. It is apparent that the irritation from a foreign body in the nose and throat may cause considerable nasopharyngeal secretion, and with the voluntary protective splinting of the pharynx possibly depressing the cough reflex pulmonary complications may be invited. There may be reason to withdraw the tube much earlier than ten days and rely on a less nourishing routine.

TABLE 3.—Operative Deaths Following Total Gastrectomy

Patient	Age	Sex	Jejunostomy (J) or Levine Tube (LT)	Direct Cause of Death	Postopera- tive Day o/ Death
3 L W	42	M	J	Bronchopneumonia *	5th
4 O B	50	M	J	Peritonitis	7th
9 G M	62	M	J	Anuria	7th
13 L S	63	M	J	Subdiaphragmatic abscess *	1st
18 H M	57	M	LT	Atelectasis and pneu- monia *	4th
19 J G	68	M	LT	Bilateral bronchopneu- monia *	10th
20 A G	70	M	LT	Cardiac insufficiency and renal failure	~9th
27 A W	63	M	LT	Bronchopneumonia and cardiac failure *	6th
29 L S	63	M	LT	Bilateral broncho- pneumonia	2nd
33 L L	70	M	LT	Cardiac failure	6th
38 H M	52	M	LT	Peritonitis (postmor- tem diagnosis)	8th
34 J B	44	M	LT	Pneumonia	~3
39 L S	63	F	LT	Cardiac failure	5th
Number Percentage					
Pulmonary complications				6	40%
Cardiac failure					2
Peritonitis					2
Anuria				1	—

* Patient also had hypoproteinemia

Of all the pulmonary complications, both those causing death and those complicating survival, there were twenty of pulmonary origin, atelectasis being the most frequent. Every effort has been made to forestall this high morbidity and mortality rate, as we have described it in our post-operative care, but it has been our chief cause of trouble.

Peritonitis and formation of abscesses have been the second most serious complications, three deaths (23.1 per cent) having occurred from these causes. Two patients died of generalized peritonitis, subsequent in 1 patient to extension of a subphrenic abscess, in both patients the origin was a fissure at the esophagojejunal anastomosis with leakage. Another death from this source occurred six weeks postoperatively, after the patient had been discharged to his home because of his insistence on release from the hospital.

The third group of operative deaths could be attributed to cardiac failure. The 3 patients, whose deaths constituted 23 per cent of the operative deaths, did not have cardiovascular systems able to withstand the increased demand that this operation places on the heart. None of these patients died in postoperative shock. While most patients were sent back to their rooms in mild shock, all save 1 responded to supportive measures within the first six hours.

Anuria subsequent to the hepatorenal syndrome was the cause of one death.

NONFATAL COMPLICATIONS

As in the case of operative mortality, pulmonary complications are the most frequent cause of postoperative morbidity. The most common trouble was atelectasis, occurring six times, pneumonia or bronchopneumonia developed nine times, pulmonary collapse presented twice and asthma, mediastinal emphysema and pleural effusion were diagnosed one time each. Cardiac conditions were usually primary causes of death.

Of the abdominal complications, one of the most troublesome has been formation of fistulas. In all this has occurred eight times, though in most instances fistulas have closed in a few days when the Levine tube has been left in place, allowing complete rest of the esophagojejunal stoma. In 1 patient the fistula caused so much subsequent formation of scar tissue that stenosis resulted and a jejunostomy for feeding purposes had to be performed. In 2 other patients bougienage and dilation were necessary to relieve stricture formation. The remainder healed without further complications. There were 2 patients in whom leaks were demonstrated with subsequent localized peritonitis, these subsequently succumbing to subphrenic abscesses. One sub-diaphragmatic abscess subsided without treatment. It is therefore apparent that the technical difficulties consequent to anastomosing a wall devoid of serosa is one of the greatest problems in this procedure. This factor, plus the routine presence of virulent organisms in gastric

cancer and the necessity of doing open anastomoses to preserve the already impaired circulation of the distal esophagus, leaves as potential a field for postoperative infection as is found in any procedure in surgery of the gastrointestinal tract.

Serious wound infections occurred in 6 cases, a fact which was not unexpected, but there have been no disruptions of wounds. One of the infections occurred in a patient who died from generalized peritonitis.

In only 1 patient was intermittent severe diarrhea a great problem. It responded to large quantities of dilute hydrochloric acid, as much as 60 cc being given in divided doses daily through the tube. This is not an uncommon brief and transitory problem during orojunal feeding and has always responded well to simple omission of the lactose in the formula and the administration of hydrochloric acid by tube.

Significant postoperative hypoproteinemia has occurred nine times in this series, but in only 4 patients was it difficult to correct with plasma transfusions at frequent intervals, supplementing the high protein feedings. These particular patients had more severe complications as well which led to their deaths.

Parotitis and pellagra each occurred one time and responded rapidly to appropriate treatment.

gastrectomy does not interfere with digestion of fat. It was also shown that this failure to absorb fat was in no way related to lack of gastric chyme or to altered motility of the gastrointestinal tract, or to deficiency of bile salts.

No consistent anomaly of protein metabolism has been noted, but a patient who had a total gastrectomy presented a persistent fecal loss of nitrogen well above the average. This altered metabolism in this patient was related to the amount of dietary protein and also influenced by the intake of fat, since there was a greater creatorrhea with increased ingestion of fat. In 2 patients who had total gastrectomy and in 1 investigated by Farris, no anomaly of protein metabolism was noted. Since metabolic studies on this patient with creatorrhea were done one year after the operation, in contrast to an interval of almost five years in Farris' case, it may be that the functions of protein metabolism may be completely taken over in time by pancreatic trypsin and erepsin of the small intestine.

Farris and his colleagues have shown that absorption of glucose in totally gastrectomized persons is more rapid than normal and results in an early pronounced hyperglycemia which falls rapidly to hypoglycemic levels even by the second hour in glucose tolerance tests, with the lowest levels appearing during the third hour, followed by a slow recovery to fasting levels during the fourth and fifth hours. They attributed these changes to alterations in absorption, utilization or rate of deposit of glucose, because with intravenous glucose tolerance studies, normal curves were obtained. They also showed that these pronounced hypoglycemic levels manifest during the glucose tolerance tests might be the explanation of attacks of weakness, vertigo and palpitation sometimes observed following partial gastrectomy. Five of our patients with symptoms of this type showed normal glucose tolerance reactions.

Six patients subjected to total gastrectomy were studied with respect to the problem of hypoprothrombinemia, and all showed a 22 to 45 per cent drop from preoperative concentrations. It is felt that this hypoprothrombinemia which is somewhat refractory to the parenteral administration of large amounts of vitamin K is most likely on the basis of hepatic dysfunction, and yet this phenomenon does not improve rapidly after gastrectomy.

Three patients who had total gastrectomy manifested a moderate anemia of the normochromic normocytic type, a macrocytic type was not seen in any patient. Studies indicated that the anemia was not due to a deficiency of dietary protein, intrinsic or extrinsic factors or destruction of blood due to infection. Four of Farris' patients survived longer than two years, and none showed evidence of macrocytic anemia. Farris and his co-workers have noted that in some of their patients a hypochromic microcytic anemia of an iron deficiency type developed which

responded to ferrous iron taken one week out of each month. They call attention to the fact that the inorganic iron normally contained in foodstuffs in the ferric form is no longer available for absorption since there is no hydrogen ion to reduce the ferric to the ferrous form for gastrointestinal absorption and that ferrous iron should be given to these patients one week out of every month.

The ablation of such an important organ therefore has a varied affect on metabolic economy. While a few patients undergoing total gastrectomy may gain a little weight their usual failure to do this is a common complaint. In great part this may be due to their inability to conserve fat. Whether or not this accounts for a consequent loss of fat-soluble vitamins has not been determined though it has been shown

TABLE 4.—*Survivors of Total Gastrectomy*

Patient	Age	Sex	Involvement of Node	Date of Operation	Survival Index (Months)
A Living and Well					
16 D G	52	F	No	7/10/47	47
17 G W	60	F	No	5/27/47	4
23 D F	58	M	No	8/2/47	-
24 F A	61	F	No	1/3/48	-
30 I G	59	M	Yes	6/7/47	-
35 W C	47	M	Yes	5/1/48	4
36 J N	57	F	Yes	10/10/47	-
B Living with Evidence of Disease					
39 J M	63	M	No	1/1/48	16
C Living After Resection for Penetrating Lesions					
39 L A	37	F	Nonconcurrent Ulcer plus tumor	11/1/44	-
40 I R	3	M	Gastric ulcer	7/1/44	-
41 F S	40	M	Gastric ulcer	7/1/44	-

* Nonconcurrent Ulcer plus tumor (patient 39 A) and gastric ulcer (patient 40 I R).

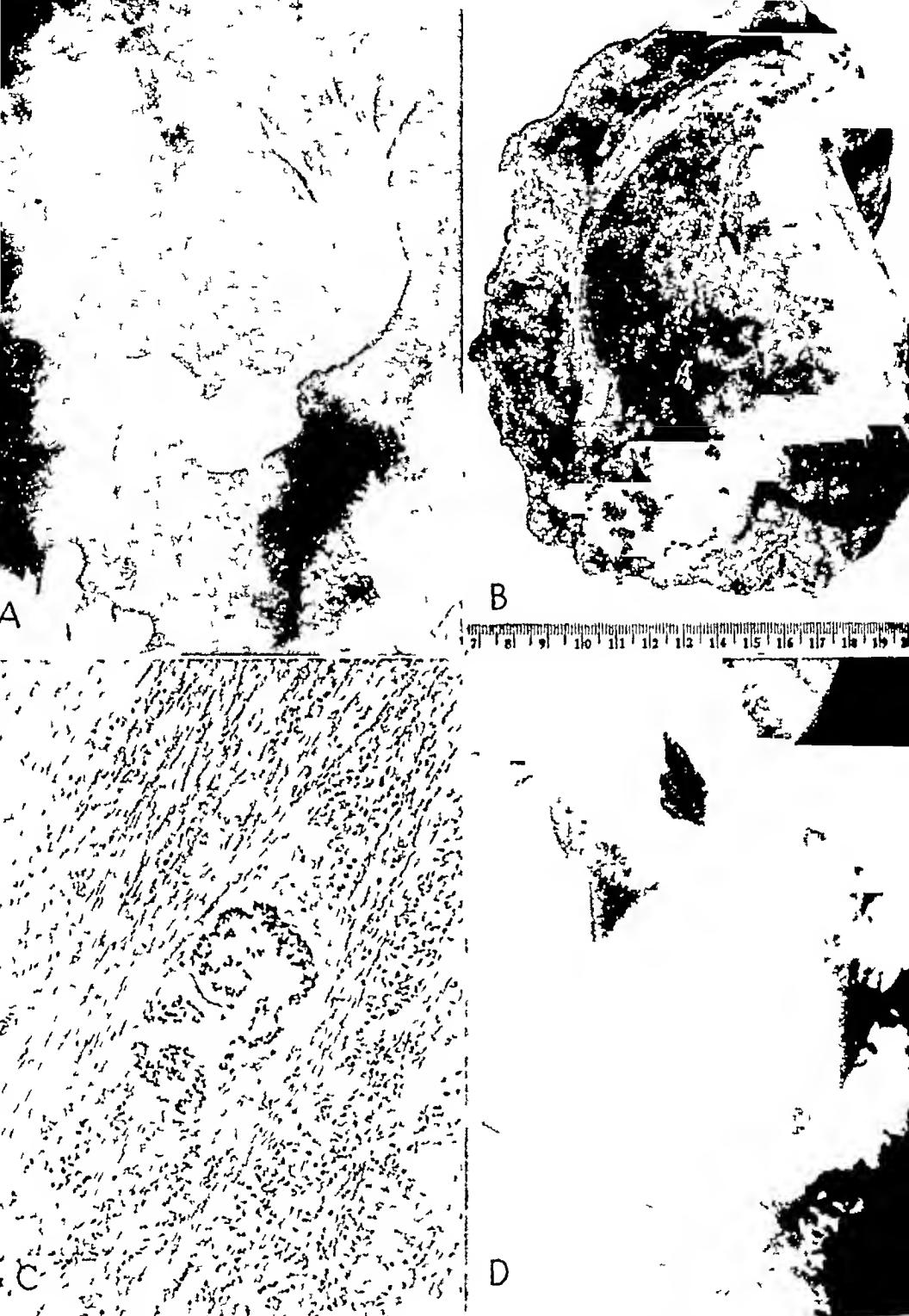
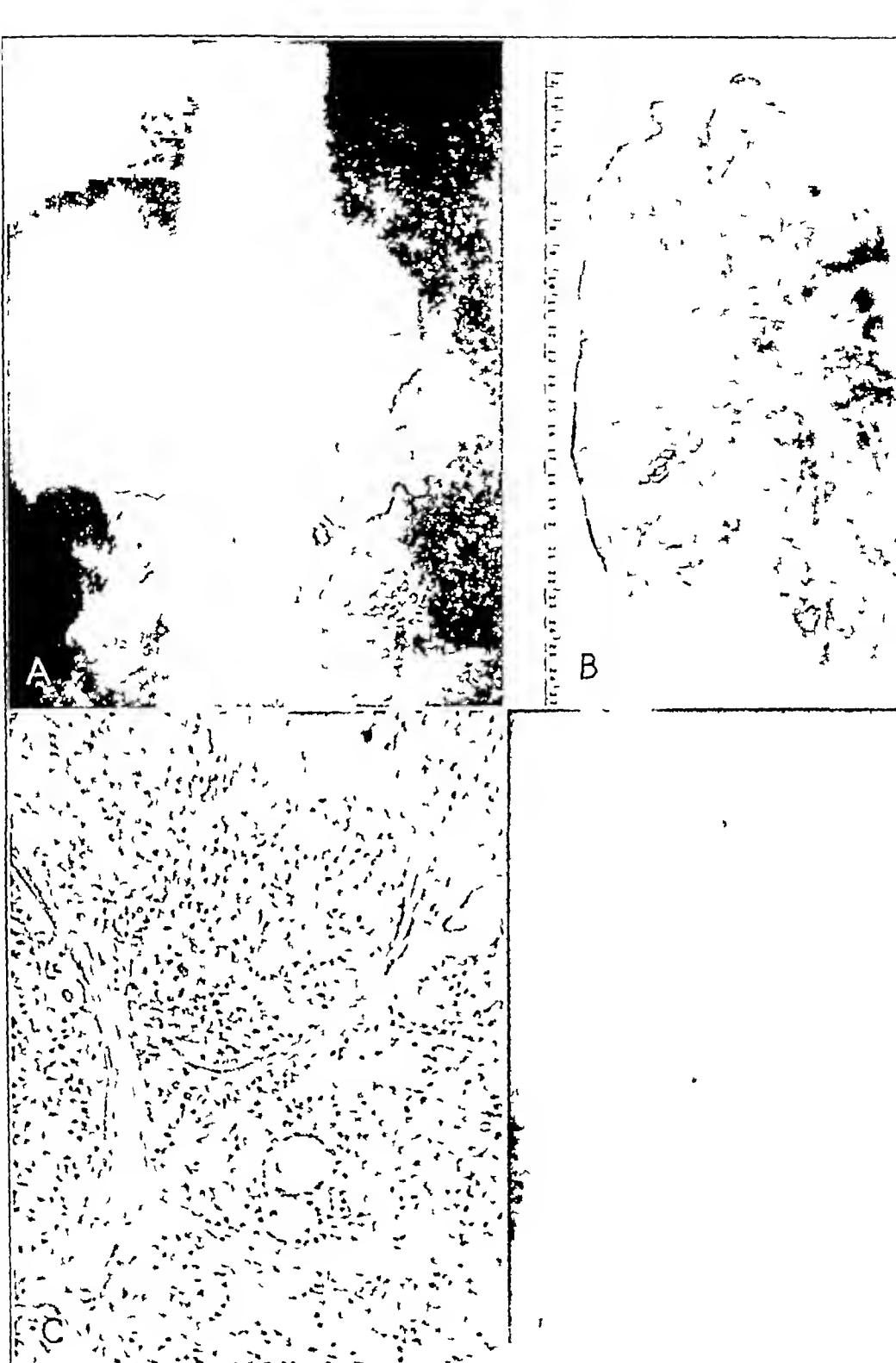


Fig 10—Patient E. A, a 64 year old woman, had symptoms of "indigestion" for eight months. *A*, preoperative roentgenogram showing marked contraction of the middle third and, to a lesser extent, the upper third of the stomach. *B*, gross pathologic specimen after opening it along the greater curvature of the stomach. Almost the entire stomach is involved with tumor which infiltrates the entire thickness of the gastric wall. *C*, photomicrophotograph showing an adenocarcinoma of varied structure from purely glandular to diffuse gelatinous to cellular signet pattern. \times approximately 195. *D*, gastrointestinal roentgenogram twenty-seven months after operation, showing smooth contour of the distal part of the esophagus and normal mucosal pattern of jejunum.



B

more than three years, the longest surviving three years and seven and one-half months. All these presented no evidence of extension to tributary lymph nodes at the time of operation. One patient whose ulcer was resected has survived over three years and four months and has no complaints except that after eating a big meal he has a sensation of fulness so that he prefers to eat four or five smaller meals per day.

TABLE 5—*Cause of Death of Survivors of Total Gastrectomy A Detailed Case Reports*

Patient	Age	Sex	Involve ment of Nodes	Date of Operation	Survival In Months	Condition at the Time of Last Examination or at Time of Death
1 M B	59	M	Yes	8/21/33	1 5	Subphrenic abscess
2 D S	42	F	No	11/9/33	26	Bone metastases
5 J C	54	M	No	3/26/40	17	Hepatic metastases
6 L S	62	F	Yes	7/2/40	8	Recurrence
7 A Z	59	M	No	8/18/40	48 5	Metastases in hernia and cul de-sac
8 F B	61	M	No	9/10/40	10 5	Hepatic metastases
10 F F	55	M	No	7/2/41	42	Possible recurrence
11 F B	46	M	Yes	11/7/41*	28	No information
12 L R	55	F	No	3/31/42	23 5	No evidence of disease accidental death
14 E L	65	F	Yes	5/6/42*	24	Recurrence near scar
15 C W	46	F	No	5/13/42	38	No information
20 E W	46	M	No	2/1/43	12	Recurrence and metastasis to liver at nine months postoperatively
21 H G	46	M	Yes	2/3/43	8.5	Metastases to liver and pelvic deposits
22 M L	50	M	Yes	5/5/43	5 5	No information
25 I K.	42	F	Yes	4/24/44	10	Nodule in scar and large pelvic mass
28 S G	58	M	Yes	8/18/44	9	Epigastric masses and deposits in cul de sac
31 C S	30	M	Yes	10/ /44	3	Multiple metastases

* Palliative resection

TABLE 6—*Cause of Death of Survivors of Total Gastrectomy B Summary*

Cause of Death	Total Cases	Nodes Involved	Nodes Not Involved
Total cases	17	9	8
Metastases	8	4	4
Recurrence	3	2	1
Metastases and recurrence	1		
Subphrenic abscess	1	1	
No information as to condition at time of death	3	2	1
No evidence of disease, accidental death	1		1
Average survival in months	17 8	10 3	26 3

(fig 3) Three patients are living postoperatively less than six months, but all had lymph node metastases and a good prognosis cannot be offered to them.

The 17 patients who survived the operation, but died subsequently, lived an average of eighteen months. Of this group there is no information as to the cause of death of 2 and 1 died an accidental death two years after her operation. The remaining 14 died of their original cancer.

Nine of the patients in whom extension of the cancer to the regional lymph nodes was found at the time of operation survived an average

bacilli. The local physician induced and maintained pneumothorax. Since the patient's condition was progressively becoming worse, he was advised to vacation in Tucson, Arizona, where no improvement was noted. At the time of admission to this hospital he was unable to climb a flight of stairs without dyspnea, palpitation and vertigo. A loss in weight of 45 pounds (20.4 Kg) had occurred, and

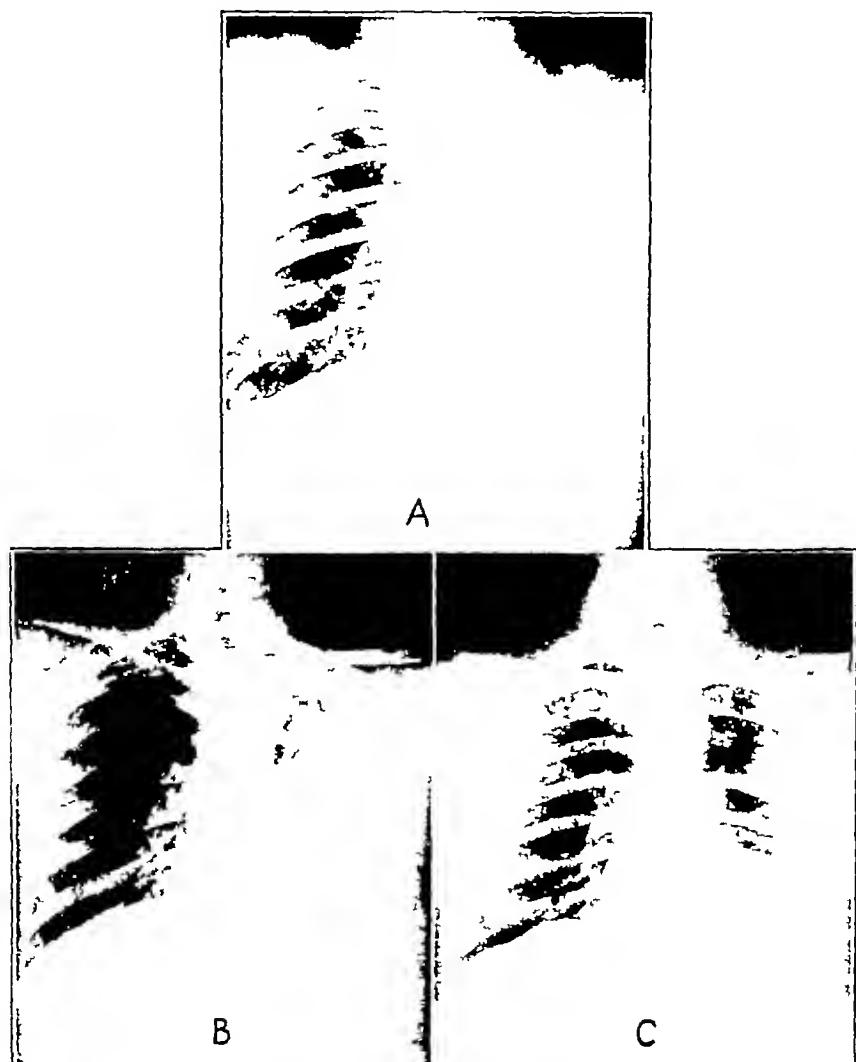


Fig 1 (case 1)—*A*, this roentgenogram shows marked thickening of the left pleura, a small amount of fluid, narrowing of the left interspaces and elevation of the left side of the diaphragm. *B*, roentgenogram taken five months later shows complete expansion of the chest wall. *C*, one year later with further clearing of pleuritis.

the patient no longer was able to conduct his business as a contractor. There was no history of cough or expectoration. Examination revealed a marked decrease in size of the left side of the chest and no motion on deep inspiration. Vibratory phenomena were absent on the involved side. Roentgen rays (fig 1*A*) showed

marked thickening of the left pleura, a small amount of fluid, narrowing of the left interspaces, and an elevation of the left side of the diaphragm. A bronchogram did not reveal bronchiectasis or obstruction, and the underlying lung appeared to be free of pathologic change.

In view of the negative bacteriologic studies and absence of pulmonary lesions, decortication was carried out on July 20, 1946. The peel or pyogenic scar varied from $\frac{1}{2}$ to 1 inch (1.27 to 2.54 cm.) in thickness. Some difficulty was encountered in its removal, and at several points a small amount of visceral pleura was torn. The lung expanded readily, but much to our consternation we noted its volume was much greater than that of the left thoracic cage. Indeed, on complete expansion the lung herniated well outside of the contracted and fixed chest wall. In order to mobilize and expand the wall, it was decided to remove the peel from the parietal and mediastinal pleura as well. This was accomplished, and the enlarged pleural space now held the fully expanded lung. Postoperatively continuous negative suction was applied. Convalescence was uneventful, and the

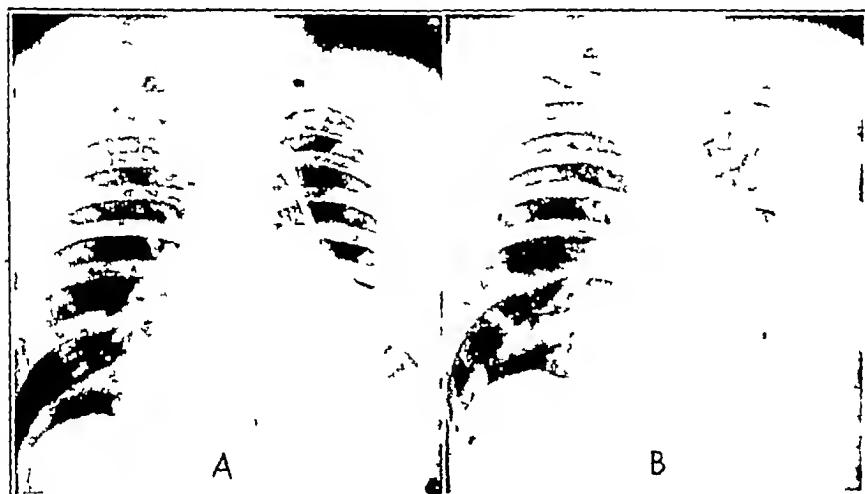


Fig. 2 (case 2).—A, the roentgenogram shows a wide pneumothorax space with compression of the underlying lung. B, there is complete expansion of the lung four weeks after discharge from hospital.

patient was discharged on the twelfth postoperative day. Figure 1B a roentgenogram taken five months later, shows complete expansion and excellent motion of the chest wall. In a recent check-up (fig 1C) the patient stated that he was able to carry on all business activities and had regained his normal weight and strength.

CASE 2.—A 42 year old white man was admitted to the Wisconsin General Hospital on Oct 23, 1946, with a chief complaint of "pus in the chest." He dated the onset of his illness to July 23, 1946 when he suffered a thoracic gunshot wound, which was followed by a pyohemothorax. Tube drainage and irrigations at a local hospital controlled the infection, but the lung became fixed and non-expansile. At the time of admission the patient did not appear acutely ill. A tube drain was present in the ninth interspace at the posterior axillary line. Thoracic signs were compatible with those of a pneumothorax on the left side. Fluoroscopy revealed little if any movement of the left lung on respiration. Roentgen rays (fig 2 A) demonstrated a wide pneumothorax space with compression of the under-

lying lung. Continuous negative suction was unsuccessful in expanding the lung. On Nov 20, 1946, four months after the initial trauma, decortication was performed. A cleavage plane between the pyogenic membrane and the lung was readily found and the peel removed from the visceral and parietal pleuras. The lung was completely expanded and the chest closed. Continuous intrapleural negative suction of —14 cm of water was maintained for three days. The postoperative course was uneventful, and the patient was discharged ten days after his operation. Figure 2B shows complete expansion of the lung four weeks after discharge.

The goal of an ideal surgical procedure is to correct adequately the pathologic condition but at the same time to maintain normal function and anatomic relationships. Thoracoplasty achieves the first objective but fails completely in fulfilling the remainder. When successful, decortication preserves the chest wall and permits a physiologic restoration of pulmonary function. Therefore, in the treatment of acute and chronic pleural effusions, decortication would appear as the operation of choice. The only exception would be a certain group of tuberculous empyemas, which will be discussed later.

Our 2 cases presented two problems not ordinarily seen in acute or early cases of inexpandile lungs. In chronic effusions it is necessary to remove the parietal, mediastinal and possibly the diaphragmatic pleuras as well as the visceral pleura. Nature in attempting to obliterate the pleural space shingles the ribs on one another, draws the mediastinum to the involved side, elevates the diaphragm and splints the thoracic cage by the application of a heavy scar on the parietal pleura. These compensatory changes produce (1) a small pleural space and (2) a fixed, functionless chest wall. The restoration of a normal anatomic relationship and function can be accomplished only by the removal of the binding scar from the thoracic cage.

These 2 cases demonstrate a relationship between ease of dissection and the chronicity of infection. In the second case, of four months' duration, the cleavage plane was readily found and the pyogenic membrane removed without undue trouble. In the first case the effusion was of seven months' duration, and the membrane and visceral pleura were difficult to separate at various points because of their intimate attachment. The pleura was torn at these points, and air leaked on full expansion. It is imperative in such instances to maintain full expansion by continuous negative suction. Failure to do this may result in pulmonary collapse and recurrence of the original lesion.

Besides chronicity of the effusion, the type of inflammatory exudate may influence the amount and extent of adherence of the inflammatory membrane. In effusions in which polymorphonuclear exudation predominates, fibrin is deposited on the pleura. There is later replacement by fibrous tissue although the fibrin is lysed by fibrinolysins released by destroyed polymorphonuclear white blood cells. This action may aid

in maintaining a cleavage plane between the lung and membrane. In lymphocytic effusions practically no fibrin is laid down, and there is formation of fibrous tissue directly on the visceral pleura. This may be the reason why there is greater difficulty in obtaining and maintaining a cleavage plane in this type of infection.

Previously we mentioned the possible application of decortication in tuberculous empyema. This type of effusion introduces the added factor of pulmonary tuberculosis, which must be considered before this surgical procedure can be entertained. It is important to know the extent of pathologic change in the underlying pulmonary tissue and bronchi. Obviously, if both lobes are involved decortication is useless.



Fig. 3 (case 3).—A, entire side shows a tuberculous process. B, appearance after pneumonectomy.

unless it is followed by immediate complete thoracoplasty. In the presence of tuberculous bronchitis or stenosis, reexpansion by decortication may reactivate the disease or may produce shifting of the mediastinum with overexpansion of the apparently contralateral lung. It is our opinion that decortication for tuberculous empyema with non-expansile lung should be reserved solely for those cases of disease limited to the upper lobe and with no evidence of tuberculous bronchitis. In such cases decortication following thoracoplasty of the upper part of the chest would collapse the diseased lobe and retain good function in the apparently healthy lobe.

CASE 3.—A 22 year old woman recently admitted to the Wisconsin General Hospital best illustrates most of the preceding points. Pneumothorax induced in June 1945 was complicated by an effusion and inexpansile lung. Efforts to

expand the lung were fruitless. Sputum continued to be positive for acid-fast organisms. The effusion at no time showed bacteria. Bronchoscopy shortly after admission demonstrated no evidence of acid-fast bronchitis. Ordinarily, a complete thoracoplasty would have been our first choice. However, in the hope that the lesions might be limited to the upper lobe we strongly considered decortication and thoracoplasty of the upper part of the chest. On receiving her original films (fig 3A) it was noted that the entire side had been extensively involved in a tuberculous process. Our choice now was (1) complete thoracoplasty and aspirations of the pleural cavity, (2) decortication, pulmonary reexpansion, and thoracoplasty or (3) pneumonectomy and complete thoracoplasty. Since the effusion never showed organisms, we elected pneumonectomy (fig 3B), which was shortly followed by thoracoplasty. In preferring this method of procedure we assumed slight risk of an acid-fast empyema in the residual pleural space in the future.

CONCLUSIONS

Reexpansion by decortication of chronic nontuberculous inexpandible lungs is feasible.

In chronic effusions it is usually necessary to remove the parietal pleura and occasionally the mediastinal pleura as well as the visceral pleura.

Intrapleural continuous negative suction is an important aid in maintaining expansion, particularly if the visceral pleura is injured.

The type of inflammatory exudate may influence the ease with which decortication is performed.

In certain selected cases of tuberculous empyema decortication and thoracoplasty would appear to be of value.

ENDOTRACHEAL ANESTHESIA

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AND

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MODERN endotracheal anesthesia is a technic in which the administration of an anesthetic may be facilitated and the patient benefited by an artificial extension of the tracheobronchial tree by means of a tube through which the patient's respiratory exchange takes place. Endotracheal tubes are made of materials such as rubber and plastic. When in place these tubes create a relatively nonobstructable channel through which the respiratory exchange occurs.

Basically, an endotracheal technic is one in which a tube is passed through the mouth (constituting an orotracheal intubation), through the nose (constituting a nasotracheal intubation) or through a tracheostomy opening (constituting a tracheostial intubation). Intubation may be performed under direct vision by the use of a laryngoscope or by the so-called "blind" technic, the tube being maneuvered through the glottis by skilful manipulations. Successful intubation requires considerable practice and a good knowledge of the structure and the functions of the upper respiratory passages.

The competent anesthesiologist must be a master of both technics, prepared to use whichever is indicated in any given situation. There are patients in whom pathologic conditions of the mouth or throat render visualization of the larynx impossible or extremely difficult, and blind intubation is essential. Conversely there are circumstances which make direct intubation the method of choice.

If an airtight system is required, it may be achieved by including an inflatable rubber cuff around the tube to make tight contact with the trachea. Similar results may be accomplished by the use of a pack. This pack usually consists of a half inch (1.27 cm.) gauze roll which

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has been impregnated with liquid petrolatum. This gauze is then firmly packed around the endotracheal tube above the laryngeal orifice. This seals the pharynx from the respiratory passages, thus preventing foreign material from getting into the respiratory passages.

Many advantages are derived from the use of the endotracheal techniques, but basically they may be classified in five main groups:

ADVANTAGES OF ENDOTRACHEAL TECHNIC

1. The first group of advantages are those which result from the free and relatively nonobstructable airway.

Many of the most distressing difficulties encountered during general anesthesia result from respiratory obstruction, due frequently to falling back of the tongue or intractable laryngospasm. Such complications endanger the patient's welfare and his life. They also may seriously hamper the surgeon in the performance of an abdominal operation by causing straining and exaggerated respiratory movements. Endotracheal anesthesia obviates these difficulties.

As a result of the tube being placed in the larynx, one has to all intents and purposes eliminated the grunting reflex by removing one of its components, the adduction of the cords. The grunting reflex, therefore, will not be seen in patients who are intubated.

One of the original reasons for the development of endotracheal anesthesia was to facilitate operations on patients partially obstructed by masses encroaching on the respiratory passages. As a result of the relative nonobstructability of the endotracheal tube, these masses do not cause obstruction. Thus one creates a clear respiratory passage in spite of such lesions as large carcinomas of the tongue, pharynx, thyroid, larynx and other organs.

An endotracheal tube may be left in place postoperatively when it is anticipated that swelling will occur under rather firm dressings, with a possibility of obstruction of the respiratory passages. The tube then remains in place until such time as the fear of edema has passed. This is applicable in cases in which are performed such procedures as mandiblectomy, bilateral radical cervical dissections and similar operations in which firm dressings are desirable and in which extensive procedures have been performed in the region of the respiratory passages.

The patient who is partially obstructed preoperatively owing to masses or edema in the area of the pharynx or larynx may become completely obstructed when consciousness is lost as a result of general anesthesia. It is, therefore, necessary in some instances to intubate these patients under topical anesthesia prior to the commencement of general anesthesia. Once the tube is in place, this patient has a better airway than was present before.

As a preliminary to tracheostomy intubation can relieve the urgency of the situation and permit the surgeon to proceed calmly and judiciously while the patient remains well oxygenated. In some instances of temporary obstruction, intubation may be substituted for an otherwise unavoidable tracheostomy.

2 The second group of advantages are those resulting from the fact that the hands and apparatus of the anesthetist may be removed from the head area, leaving the surgeon a clear operative field. Thus one is able to do such operations as those on the mouth, tongue, palate, jaw and face with nothing more than a small rubber tube in some portion of the operative field. This can be adequately draped so that the surgeon may have a relatively sterile field.

3 The third group of advantages are those resulting from the ease with which control of respiration and artificial respiration may be accomplished.

Artificial respiration may be easily accomplished by mere manual pressure on the breathing bag or by blowing down the tube. The possibilities of failure to inflate the lungs due to obstruction or of inflating the stomach are avoided.

With endotracheal anesthesia one is able to supplement the respiration of those who, owing to various and sundry factors such as general debility, open chest, diseases of the lungs, toxic or drug depression, have a diminished respiratory exchange. By gentle pressure on the breathing bag as these patients inhale one is able to increase the amplitude of the inspiration, thus producing better aeration of an otherwise hypoxic patient.

A further development is "controlled respiration," a method whereby spontaneous respirations are eliminated and inflation of the lungs is carried out by the anesthesiologist and timed to give the surgeon the optimum working conditions.

4 The fourth group of advantages are those that result from the elimination of the danger of aspiration of debris, blood, pus and vomitus.

These benefits are important to those who operate on patients who have lesions of the upper respiratory tract and pharynx. In an emergency case of almost any type there may be a full stomach. It is best that the food be removed when possible and, in addition, an endotracheal tube with a cuff be used so that the vomitus will not find access to the tracheobronchial tree.

Patients with dilated gastrointestinal tracts frequently regurgitate some of the contents into the pharynx without any visible evidence of vomiting. This silent vomiting would be extremely damaging if the vomitus were aspirated. Thus again the tube with the cuff gives one the assurance of a noncontaminated airway.

5 The fifth group of benefits derived from this technic is that removal of material from the tracheobronchial tree may be accomplished with ease by inserting a suction catheter through the tube

This aspiration may be accomplished before, during or after the operative procedure. The patients most frequently requiring this bronchial aspiration are those who suffer from such conditions as pulmonary abscesses, bronchiectasis, tuberculosis and chronic bronchitis.

In many instances this technic of endobronchial aspiration may be used to treat postoperative atelectasis. It definitely does not have the certainty connected with direct visual bronchoscopic aspiration but is in many cases successful. It is usually accomplished by passing a tube with the use of topical anesthesia. This technic in the hands of those skilled in its use has the advantages of ease and speed of accomplishment. Yet, should this fail, no time should be lost in requesting a bronchoscopic aspiration.

DISADVANTAGES OF TECHNIC

Endotracheal anesthesia is not without its hazards and dangers. First among these dangers is trauma. The trauma most frequently encountered is contusion of the mucosa due to some difficulty in intubation. It is rarely severe or lasting and usually takes the form of a complaint of hoarseness or mild cough for the first day or two post-operatively. Children are most susceptible to trauma owing to the smallness of the laryngeal orifice. Another factor of considerable importance is that the submucosa is made up of loose areolar tissue which easily becomes edematous. The danger of edema of the larynx in children who have been intubated must be kept in mind, yet it is rarely seen.

Trauma as a result of allowing the tube to remain in place for long periods is not frequently encountered. In one instance a tube remained in place five consecutive days without being changed. The patient died of other causes and sections of the larynx failed to show any evidence of damage other than a slight round cell infiltration.

Bleeding is also seen as a result of attempting this technic. Most frequently it results from attempts at nasal intubation. Bleeding is rarely severe or prolonged. Another danger is that of endobronchial intubation as a result of the use of a tube that is too long. This will result in a massive atelectasis of the side opposite that in which endobronchial intubation has been performed. This complication can quickly be corrected by withdrawing the tube.

All of the dangers or hazards enumerated markedly diminish as the skill of the anesthetist increases.

SUMMARY

Thus, in summary, one might state that endotracheal anesthesia has much to offer the patient, the surgeon and the anesthesiologist. This technic diminishes many of the dangers of surgical procedures, facilitates the ease with which the surgeon may operate and renders more easily accomplishable the mission of the anesthesiologist, which is the guarding of the safety of the patient while at the same time aiding and facilitating the surgeon's activity. This technic, good in the hands of the competent anesthesiologist, has hazards which increase tremendously in the hands of the incompetent.

A DOUBLE-LUMENED PLASTIC TUBE FOR INTESTINAL INTUBATION

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WYANDOTTE, MICH

AND

HOMER M. SMATHERS, M.D

DETROIT

DECOMPRESSION of the small bowel by intestinal intubation is now a well established surgical principle. Many persons, while recognizing the value of this procedure, have experienced difficulties in the passage of the tube beyond the pylorus and in maintaining adequate suction. It has therefore seemed worth while to develop a type of tube which can be more easily passed even in the hands of those using the procedure only occasionally. A good general discussion of the problems associated with the technic of intestinal intubation has been presented by Johnston¹.

Abbott and Johnston² in the first article to appear on the use of intubation of the small bowel in obstruction, emphasized that "the ideal tube should have two lumina, one very large for the aspiration of intestinal content and one very small for the introduction of air into the balloon." Other criteria for the ideal intestinal tube are that it should be flexible enough to follow the contour of the bowel easily yet rigid enough to prevent kinking and not to collapse on suction. It must be nontoxic, opaque to fluoroscopy and easily introduced into the gastrointestinal tract. Various types of tubes now on the market have been investigated, and none has fulfilled all these requirements. Further, these tubes are of rubber, and in recent years good tubing has been difficult to obtain besides being costly.

Plastic tubing appeared to us to offer certain advantages, and during the past two years we have used various types of tubing made from this substance. The tube presently in use fulfills all the requirements men-

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1 Johnston C. G. The Technic of Intestinal Intubation, in Nelson Loose Leaf Surgery, New York, Thos Nelson & Sons, 1927, pp 651-662.

2 Abbott, W O, and Johnston, C G. Intubation Studies of the Human Small Intestine X A Non-Surgical Method of Treating, Localizing and Diagnosing the Nature of Obstructive Lesions, Surg, Gynec & Obst. 66 691-697 (April) 1938.

tioned, withstands boiling without rapid deterioration and has the further advantage that intestinal odors are readily removed by washing.³ The tubing is made of a plastic, Geon polyvinyl chloride, impregnated with a nontoxic radiopaque material. The large lumen for suction has a bore equivalent to that of a no 16 French tube. The wall is slightly thinner than that of the Miller-Abbott or the Jutte tubing. The smaller tube has a lumen which just admits an 18 gage needle. The two tubes are extruded at once into a double tube unit having a smooth contour. The relative size and contour of this tube as compared with others generally in use are presented in figure 1. With this plastic tube we have combined the principle of an inflatable balloon, first suggested by Miller and Abbott,⁴ and that of the use of mercury in this balloon, a principle first suggested by Harris⁵ and Wilkins⁶. The tube ready for use is shown in figure 2.

Several types of intestinal tubes with many modifications have been studied since April of 1945. These include (a) the Miller-Abbott tube,⁷ with and without mercury in the balloon, with the balloon either proximal or distal to the end of the tubing, (b) the Johnston tube¹

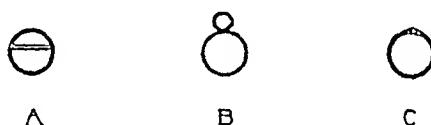


Fig 1.—A, cross section of the Miller-Abbott tube. B, cross section of the Johnston tube. C, cross section of the new plastic tube.

with and without the addition of mercury in the balloon, with the balloon proximal or distal to the end of the tubing, (c) the single-lumened rubber tube with the balloon containing mercury leading the tube into the bowel, (d) single-lumened rubber tubes with metal weights of various size and shapes attached at various distances from the end of the tubing, (e) single-lumened tubes with metal weights in tandem arrangement attached to the end of the tube, and (f) single-lumened and double-lumened plastic tubing with the balloon either proximal or distal to the end of the tube.

3 The plastic compound is made by the B. F. Goodrich Chemical Co., Cleveland. The tubing is made by Jessall Plastics, Hartford, Conn.

4 Miller, T. G., and Abbott W. O. Intestinal Intubation. A Practical Technique, Am J M Sc. 187:595-599 (May) 1934.

5 Harris, F. I. A New Rapid Method of Intubation with the Miller-Abbott Tube, J. A. M. A. 125:784-785 (July 15) 1944, correction ibid 126:718 (Nov 11) 1944.

6 Wilkins, J. A. Mercury-Weighted Stomach Tube, J. A. M. A. 91:395-396 (Aug 11) 1928.

7 Abbott and Johnston²; Harris

Whenever double-lumened tubing was used, trials were made both with mercury and air combined and with air alone in the balloon. The effect of varying the quantity of mercury was also tested.

Certain difficulties have been encountered during the use of these various tubes in the treatment of 240 patients with intestinal obstruction. Most noticeable was the plugging of the lumen of the Miller-Abbott tube by particulate matter. This was seen on many occasions and required frequent irrigations in order to keep the lumen open. The Johnston tube takes considerable time to assemble, and the two tubes when placed together seemed unduly large for the average patient's nares. The use of various solid weights leading the long tube was abandoned because of slow and uncertain passage at or just beyond the ligament of Treitz.

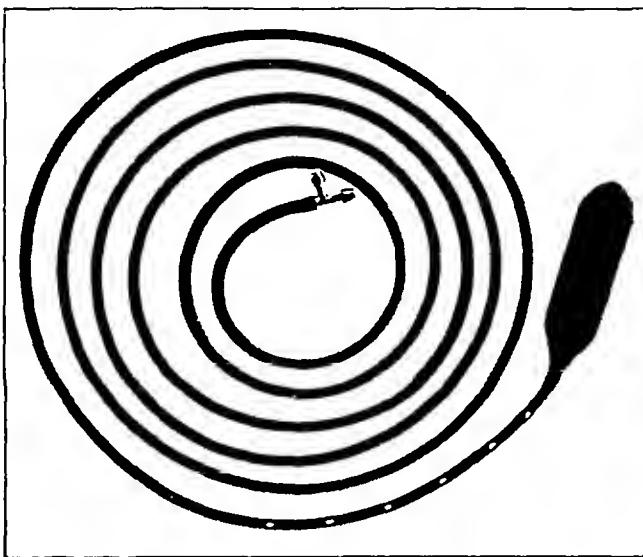


Fig. 2.—The plastic tube

Olive or round-shaped weights could be passed through the pylorus readily, but frequently the tubing would be advanced ahead of the weight in the third portion of the duodenum or in the jejunum, and the dragging metal behaved much like an anchor.

The efficacy of the double-lumened tube has often been seriously questioned. Our observations have proved beyond a doubt that the double-lumened tube is highly preferable to the single-lumened one. The chief difficulty with the single-lumened tube with mercury is the inability to control it once it has passed into the small bowel. Inability to inflate the balloon requires that the tube progress almost entirely by the weight of the mercury, because the diameter of the balloon is too small for the bowel to obtain adequate purchase for peristalsis. In our experience the slowest passage of the single-lumened tube occurred in cases of tre-

mendous dilatation of the small bowel, in which the need for rapid decompression was greatest. With the double-lumened tube, the balloon can be inflated when it reaches distended bowel, and peristalsis rapidly carries the larger object forward. The reason for this will be apparent from a study of figure 3.

Several techniques for intestinal intubation have been reported.⁸ It should be emphasized that no one type of procedure will adapt itself to all patients. The patient's condition frequently dictates caution rather than an overzealous effort at manipulation on the fluoroscopic table. In general, our method for passage of a long tube is as follows. After instilling a 1 per cent solution of tetracaine hydrochloride, butacaine sulfate or any other mild local anesthetic agent into the nostrils by drops or spray, the tube lubricated with petrolatum and with the balloon containing 2 cc of mercury is inserted through the nostril with the patient supine. A curved hemostat, stylet, or forceps may be used to aid in this step.

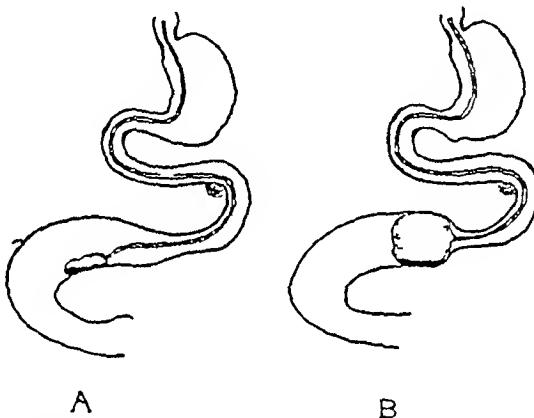


Fig. 3.—A, distended small bowel with mercury-weighted tube. B, distended small bowel with inflated balloon and mercury.

With the mercury in the balloon pulling the tube into the pharynx, the patient is instructed to sit up and swallow. The tube then drops rapidly into the stomach. If the patient can safely be transported, the use of a fluoroscopic table will greatly facilitate the procedure, as the position of the balloon can be checked by fluoroscopy. If the tube is passing toward the pylorus, slack is given and the patient is turned on the right side. When the balloon is at the pylorus, the head of the table is elevated in order that the tube may fall into the duodenum. When it is in the second or third portion of the duodenum, 10 to 20 cc of air is injected.

⁸ (a) Harris, F. I. Intestinal Intubation in Bowel Obstruction Technic with a New Single Lumen Mercury Weighted Tube, *Surg., Gynec. & Obst.* 81:671-678 (Dec.) 1945. (b) Abbott, W. O. Indications for the Use of the Miller-Abbott Tube, *New England J. Med.* 225:641-646 (Oct. 23) 1941. (c)

into the balloon. With this bulk the tube frequently passes forward rapidly with peristaltic rushes. Once in the jejunum, another 20 cc of air is added. The tube is then allowed to pass as rapidly as peristalsis permits. It should be emphasized that constant suction is essential to forward progress of the tube, for only as the walls contact the balloon can peristalsis act on it (fig 3). Recently we have been using a suction pump⁹ which removes intestinal contents more constantly than the Wangensteen suction.

Once progress of the tube is halted, roentgenograms are taken to make certain that the bowel is completely decompressed. After decompression and restoration of the patient to a more normal physiological status, the point of obstruction may be localized by means of a small amount of barium injected through the tube¹⁰.

The procedure as described may have to be varied in the case of critically ill patients. In these patients the tube may be inserted in the admitting room and the patient placed right side down and taken for roentgen examination. The usual diagnostic flat plates will also reveal position of the tube. If its direction is satisfactory, suction is attached and 2 inches (5 cm) of slack is given every thirty minutes. If the tube is found to be directed toward the cardia, it is pulled back and the patient is again turned on his right side. Roentgenograms are taken at six hour intervals, and as soon as the balloon is in the second or third portion of the duodenum, air is inserted as mentioned before.

From 1938 to 1945 air alone was used in the balloon with the double-lumened tube. Although a high percentage of tubes were successfully passed by this technic,¹¹ it was frequently necessary to spend long periods in the fluoroscopic room with an extremely sick patient. Not only was this difficult for the patient but it also involved considerable exposure to radiation for both patient and surgeon. Much manipulation was necessary and frequently a wire stylet was required to direct the tube into the duodenum.¹² We believe that the addition of mercury to the balloon is a distinct advance. We have also learned that there is considerable advantage in having the balloon beyond the tip of the tube since this allows a wider range of motion for the mercury than does a

⁹ Crowley, R. T., and Johnston, C. G. Physiological Principles in Intestinal Obstruction, *S Clin North America* **26** 1427-1439 (Dec.) 1946.

¹⁰ Lofstrom, J. E., and Noer, R. J. The Use of Intestinal Intubation in the Localization of Lesions of the Gastro-intestinal Tract, *Am J Roentgenol* **42** 321-329 (Sept.) 1939, The Role of Intestinal Intubation in the Diagnosis and Localization of Intestinal Obstruction, *Radiology* **35** 546-556 (Nov.) 1940; Golden, R., Leigh, O. C., and Swenson, P. C. Roentgen-Ray Examination with the Miller-Abbott Tube, *ibid* **35** 521-533 (Nov.) 1940.

¹¹ Johnston, C. G. Decompression in the Treatment of Intestinal Obstruction, *Surg., Gynec. & Obst.* **70** 365-369 (Feb 15) 1940.

proximally placed balloon. The fact that the inflated balloon passed rapidly without a suction tip proximal to it indicates that there is some passage of intestinal contents between the bowel wall and the balloon.

The new plastic tube has been used in treating 50 patients with intestinal obstruction. The average time for passage from the nose into the middle or lower part of the ileum was twenty-four hours. This time is usually shortened in the more severe cases, but the average remains at twenty-four hours because many show so much improvement after gastric and duodenal suction that efforts are not extended to advance the tube rapidly. This tube has been more satisfactory than any other which we have used so far as ease of introduction and effectiveness and rapidity of decompression are concerned. To date there has been no instance of ulceration of the mucosa even though the tube was in place for thirty-five days on one occasion and twenty-three days on another.

Three case reports are cited as typical.

CASE 1.—J. P., a Negro aged 68, entered the hospital with a diagnosis of peritonitis of unknown cause. Roentgenograms made with the patient in supine and erect positions revealed severe ileus. The double-lumened plastic tube was inserted as soon as he arrived on the ward. He was given a fluoroscopic examination two hours later, and the balloon was seen in the third portion of the duodenum. It was inflated with 20 cc. of air and advanced beyond the ligament of Treitz in but a moment. Another 20 cc. of air was injected into the balloon, and a roentgenogram made four hours later revealed the tube to be at the ileocecal junction. Subsequent operation revealed a ruptured gallbladder with a walled-off abscess. The postoperative course was excellent.

CASE 2.—J. L., a white woman aged 37, was admitted one month after a pelvic operation at another hospital. The pulse and blood pressure were unobtainable. Blood and plasma were administered immediately, and the double-lumened plastic tube was passed. Though there were some indications for immediate exploration, her general condition would not permit the procedure. Response to fluids and decompression was so remarkable after eight hours that immediate operation no longer appeared necessary. After restoration of a more normal fluid and electrolyte balance, localization was carried out through the tube. One week after her admission, operation through a small right transverse incision was carried out, and a bind adhesion found at the previously localized site was severed. Her recovery was uneventful.

CASE 3.—M. B., a Negro woman aged 52, entered the hospital with acute distention and with a history of chronic intestinal obstruction. The blood urea was 280 mg. and the serum chlorides 300 mg. per hundred cubic centimeters. The double-lumened plastic tube was passed in the ward, and a roentgenogram made twelve hours later revealed the tube to be in the jejunum. The balloon was then inflated and passed rapidly down the small bowel. With decompression accomplished and the fluids and electrolytes balanced the site of obstruction was explored through a low mid-transverse incision eleven days after admission. Chronic obstruction of the small bowel was found low in the pelvis which was due to inflammatory adhesions about an old proctalgia. It was necessary to resect a segment of ileum. Recovery was complicated by an infection of the wound from which she recovered satisfactorily. The tube was well tolerated in this patient for a period of thirty-five days.

These cases are typical of the majority in which intestinal intubation is used. The tube is occasionally passed preoperatively in elective cases such as cases of large incisional hernias and of involvement of the colon, in which the procedure functions as an ileostomy. It is used prophylactically in many cases of gunshot wounds, strangulated hernias, peritonitis and traumatic ileus. We have found it to be an all-important adjunct not only in maintaining decompression but in allowing an early oral intake after the tip has passed the jejunum.

We are cognizant of the fact that the long tube has not had the general use it deserves, in large part because of the many difficulties encountered in its passage into the intestine. The use of mercury combined with an inflatable balloon obviates much of this difficulty. Use of this combination of a double-lumened tube with a large lumen for suction and a balloon containing both mercury and air should make possible successful intestinal intubation in all cases in which decompression is indicated even in the hands of those not accustomed to its use.

SUMMARY

A double-lumened plastic tube with an inflatable balloon containing mercury has been presented as a solution to many of the difficulties previously encountered in the procedure of intestinal intubation.

Experience in the use of this tube in 50 cases of acute intestinal obstruction has demonstrated its efficiency, ease of introduction and freedom from untoward complications.

Dr Charles G Johnston and Dr Rudolf J Noer rendered helpful criticism during the development of this tube.

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DEVELOPMENT OF AN ARTIFICIAL KIDNEY

Experimental and Clinical Experiences

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Assisted by

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USING heparin as an anticoagulant, attempts were made to clear the blood stream of toxic substances by transplantation of a kidney from one animal to another and from one species to another. His work was done in 1933, 1934 and 1935, with moderate success.¹ The objective in this present investigation was to prevent a patient's dying of acute toxemia in such conditions as acute poisoning by mercury and phenol, in toxemia of acute infection, such as nephritis or pneumonia, with oliguria or anuria, as well as in acute anuria following blood transfusions, administration of excessive sulfonamide drugs, eclampsia and toxemia of pregnancy, severe cutaneous burns, induced abortions and acute injury to ureters and kidneys from calculous obstructions, reflex or otherwise, or operation.

It seemed possible that if the patient could be protected from death from toxemia in such conditions, after a time there would be sufficient recovery in a number of cases so that the affected kidneys might resume function.

others on this continent but to our knowledge the work has not been developed to a point where it was a proved effective clinical method of treatment. The one exception is the work of Kolff⁴ in Holland. We were not aware of his work, and only after the war did information on his work arrive. His monograph gives evidence of his extensive treatment of patients, with some good clinical results. Our efforts have been going on apparently simultaneously and independently. It was interesting, therefore, to compare the methods and the material used and to note the different avenues followed, which evidently converge fairly closely toward the same goal of end results.

The principal aspects of the artificial kidney are (1) a dialyzing membrane which is selective in allowing the passage from the blood stream of some substances and not of others, namely, nonprotein nitrogen and other toxic substances, (2) a method of circulating the blood through this extrinsic system and (3) protection from removal of necessary substances from the blood stream.

It was after extensive and arduous trials and experiments that we finally arrived at the present setup, which works satisfactorily both experimentally and in clinical patients.

The following summary includes some of the events which led to the development of the apparatus and might be termed the evolution of this machine.

1 The first method was the circulation of arterial blood with return through the venous side through several coils of cellulose acetate tubing (sausage casing) bathed in warm tap water. This tubing was 1 inch (about 25 cm.) in diameter and presented the primary disadvantage of the ratio of volume to surface area. Also the size of the tubing allowed too much escape of the animal's blood before there was sufficient return if a reasonable length of the tubing were used. In this way the animal really had hemorrhage into the tubing. Filling this with blood beforehand overcame the difficulty.

2 Later, with considerable effort, tubing $\frac{1}{2}$ inch (127 cm.) in diameter was obtained and with this somewhat better results were obtained. Later, from the Visking Corporation of Chicago, $\frac{1}{4}$ inch (0.63 cm.) tubing was obtained, and with this fairly satisfactory results could be achieved.

3 With fairly long sections of this tubing *in vitro* we were able to demonstrate that (fig. 1) there was some passage of nonprotein nitrogen substances through this membrane and that the larger protein molecules did not pass.

³ Thalheimer, W. Artificial Kidney and Experimental Exchange Transfusion for Reducing Azotemia, Proc Soc Exper Biol & Med 37: 641, 1938.

⁴ Kolff, W. J., and Van Noordwijk, J. The Artificial Kidney Kampen, Holland, J. H. Kok N. V., 1946.

4 To diminish the volume of these tubes it was attempted at first to press the tubing through a series of wire cells containing the dialyzing tubes.

5 Next concentric wire cylinders between which the tubes were partly compressed, were used.

6 Then a wooden reel was tried on which the coils could be assembled fairly quickly. This did not control the volume satisfactorily.

7 Next it was decided to coil the tube around a small platform and on each side plastic perforated sheets were applied and bolted together to compress the tubing in the coil. These were in turn found to be unsuitable because of the bulging under the pressure of the fluid in the coil.

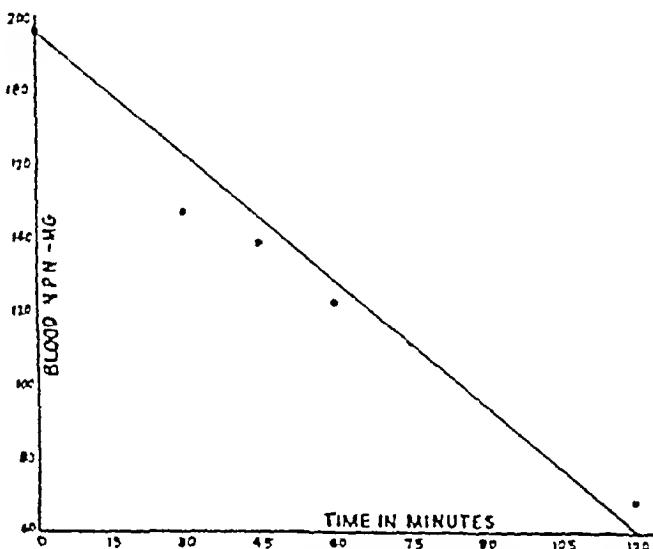


Fig. 1.—In vitro experiment on human blood, showing the fall of nonprotein nitrogen during two hours of dialysis in the artificial kidney (length of tubing 25 feet [about 777 cm]). In the two hours 2.3 Gm. of nonprotein nitrogen was recovered. No proteins came through.

8 Then sheets of the plastic plates were replaced with wood and these were found to warp.

9 These were replaced with aluminum steel plates which were bolted together with a thin definite spacing between them. This worked moderately well but was finally discarded for a vertical wire mesh.

SOURCE OF BLOOD FOR DIALYSIS

The next problem to be solved was that of a method of circulating the blood. It was decided that using an artery as the propelling force had many disadvantages. 1 The artery could be used only once. If further attempts were to be made, another vessel would be required. 2 The pressure in the system was such that there was not a satisfactory return of the venous blood by this type of pressure. Moreover, the animal tended to act as from the result of hemorrhage from arterial bleeding.

In all these methods, of course, it is obvious that the animal was highly heparinized⁵ to make sure that there was no clotting or thrombosis in the system, at the points of intake or output or in the animal itself.

It was decided to attempt to develop a system in which the blood could be taken from the venous system and then returned through another point in the venous system. On this basis, blood was taken first from femoral veins and then external jugular veins, but it was observed that with any pump system which produced suction the vessel collapsed and acted as a valve over the tube. To overcome this difficulty a catheter of fairly large diameter was passed through the femoral vessels and into the inferior vena cava or into the right side of the cardiac region. From this any quantity of blood could be removed by aspiration without any interference or obstruction, and it could be returned readily to a vein on the opposite side. This seemed to have many advantages. 1 There was no ill effect on the blood pressure of the animals, simulating hemorrhage. 2 The quantity of blood removed could be controlled accurately, which was not the case when an artery was used. 3 The unoxygenated venous blood was circulated through the system, and, therefore, more impurities were available for dialysis by this method. 4 The blood was not oxygenated, and it was easy to add oxygen to it as well as dialyze it during the circulation through the system of tubes.

PUMP SYSTEM

The next problem was in providing a circulating pump system which would not damage or crush the blood corpuscles, would not produce hemolysis, would work smoothly and would not become plugged and clotted with fibrin.

1 At first, the blood was drawn into a flask, then circulated through the dialyzer and then returned to the venous system by gravity. 2 Next, a syringe piston was used as a pump, with intake and outlet valves on glass seats, but it was early demonstrated that in spite of a high degree of heparinization, the spinning of these valves and the passage of the blood through the small apertures tended to cause some collection of fibrin and interfere with the function of the system.

⁵ Murray, G D W. Heparin in Thrombosis and Blood Vessel Surgery, Surg., Gynec. & Obst. 72:340, 1941.

3 A rotary pump effect was used, but this was only moderately satisfactory. 4 Finally, a pump system was used whereby a rubber tambour was inflated and deflated by the action of the piston-worm attached to an electric motor. Rubber intake and outlet valves gave good effect from the pump, so that smooth circulation without injury to blood and without clotting and deposit of fibrin or platelets could be carried out for many hours at a stretch.

EXPERIMENTS IN INCREASING DIALYSIS

Many efforts were made to increase the rate of dialysis through the membrane. 1 The best and most obvious way of increasing dialysis was by increasing the length of the tubing used. In the experiments lengths up to 35 feet (about 1,067 cm.) were used satisfactorily, and it would seem possible to increase this length considerably more with still more beneficial effect. 2 It was thought that by attempting to reduce the atmospheric pressure surrounding the tubing an improvement in dialysis might be obtained, but results of these experiments were not satisfactory. 3 By increasing the pressure within the dialyzing tubing it was thought that there might be some increase in the dialysis, but again this requires further study to be certain of the effect. 4 Some investigation to see whether the work described by McBain and Kistler⁶ would apply under these conditions was carried out. They indicated that the use of 64 per cent zinc chloride solution would stabilize the apertures in the membrane and would increase the rate of dialysis. Extensive tests were made with this, which covered a period of several months. Figures 2 and 3 show the results of some of the experiments with this tubing. It was our conclusion, finally, that while there was some beneficial effect in the rate of dialysis early in the exchange, in the final results there was not a great difference. It did not seem to be a sufficiently great difference to justify or warrant the effort and trouble of treating the tubing and for that reason the method was discarded and the untreated tubing was used. It was noted in our experiments that the use of zinc chloride with adequate washing afterward did not seem to produce any toxic effects in the animal.

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THE DIALYSATE

The next problem in relation to the protection of the animal against the removal of substances which are necessary for life involved a great deal of work and was the most difficult to solve. It was observed that if an animal's blood were dialyzed through this machine with a sur-

⁶ McBain, J. W., and Kistler, S. S. Membranes for Ultrafiltration, of Graduated Fineness Down to Molecular Sieves, *J. Gen. Physiol.* **12**, 187, 1928, Hydration of Sucrose in Aqueous Solutions, *J. Phys. Chem.* **33**, 1895, 1929, Ultra Filtration as a Test for Colloid Constituents in Aqueous and Non-Aqueous Solutions, *ibid.* **35**, 139, 1931, Membranes for High Pressure Ultrafiltration, *Tr. Faraday Soc.* **26**, 157, 1930.

rounding bath of tap water within five to seven minutes the animal showed striking clinical changes. The rate of breathing was accelerated to the point of violence. There were shock and collapse, and the animal died within a period of seven to fifteen minutes.

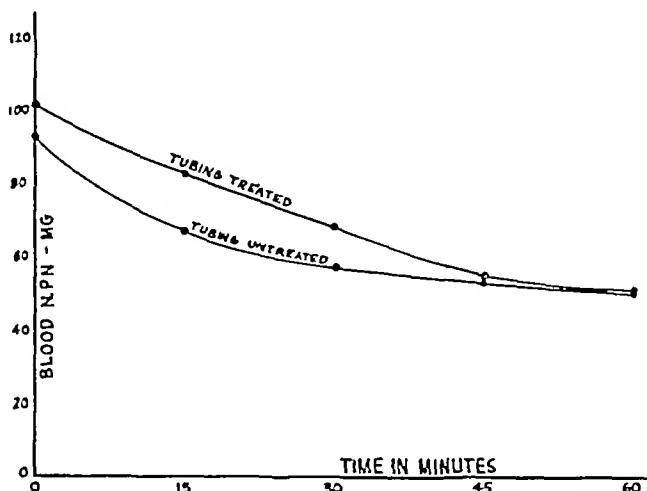


Fig. 2.—Graph showing the relative efficiency of tubing treated with zinc chloride and untreated tubing in removing nonprotein nitrogen from human blood (in vitro).

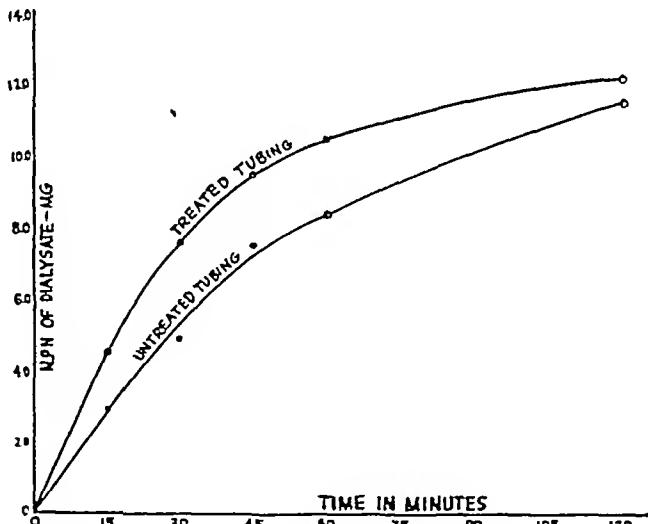


Fig. 3.—Graph showing the amount of nonprotein nitrogen recovered in the dialysate when dialyzing urea from an aqueous solution in vitro and the rate of dialysis with untreated tubing as compared with tubing treated with zinc chloride.

We were not certain at this stage whether important substances, such as epinephrine, pituitrin, insulin, heparin and so on, were being removed and whether the animals were going into shock on this account. As the chemical tests for some of these substances are difficult

and uncertain, we were not convinced by chemical analysis whether such was the case or not. However, we arrived at our final conclusions by the following methods.

During dialysis it was demonstrated that the animal had an increasing concentration of hemoglobin (table 1) and that he showed evidences of loss of water. It was decided, therefore, to balance the

TABLE 1.—*Results of Dialysis in Vivo in Blood of Dog During Two Hundred and Twenty Minutes of Perfusion, Using Warm Running Tap Water as the Dialysate*

Sample Number	Time of Test	Nonprotein Nitrogen, Mg /100 Cc	Chloride *	Hemoglobin, per Cent
1	Before dialysis	40		91
2	After 40 min	48	562	95
3	After 90 min	44		
4	After 130 min	56		
5	After 160 min	60		
6	After 200 min (after 4 Gm urea given intra-venously)	100		
7	After 220 min (blood entering artificial kidney)	54	464	103
8	After 220 min (blood leaving artificial kidney)	41	360	

* There is a continuous fall in the blood chlorides and a rise of hemoglobin, indicating a loss of chlorides and of water.

TABLE 2.—*Changes in Blood in a Dog After One Hundred and Ninety Minutes of Perfusion with the Artificial Kidney*

Sample * Number	Time of Test	Blood Nonprotein Nitrogen, Mg /100 Cc	Hemoglobin, per Cent	Red Blood Cell Count
1	Before dialysis	37	90	5.5
2	After 15 min	40	79	5.4
3	After 70 min	35	78	5.1
4	After 130 min.	37	91	6.1
5	After 190 min (blood leaving artificial kidney)	42		
6	After 190 min (blood from artery, after contents of dialyzer returned to animal †)	37		

* The dialysate was 20 liters of isotonic solution of sodium chloride.

† With isotonic solution of sodium chloride as the dialysate the animal was in good condition after one hundred and ninety minutes of dialysis.

dialysate by surrounding the tubing with some of the normal substances in blood, as indicated in Ringer's solution. It was observed that on addition serially of each of these substances we could overcome one or the other of the difficulties and could carry on a dialysis without having these disastrous effects on the animal. When the chlorides, calcium, magnesium, potassium, sodium, phosphate, carbonate and sugar were balanced in turn, we observed that these disastrous effects in the animal did not occur (table 2). It was observed in the preparation of our dialysate that with the potassium left out the animal suffered ill effects and when potassium was added he was protected against these effects.

Results were similar with the other salts and sugar. Variations in the p_{H} also caused alarming results. It was necessary to add the bicarbonate to the solution to preserve the p_{H} at a level of about 7.3. With the dialysate at this p_{H} there was no change in the blood p_{H} during or after dialysis.

However, as both quantitative and qualitative tests for some of these chemicals are difficult and unreliable, it was difficult or impossible to prove the specific effect of the lack of potassium, calcium and so forth, although the experimental proof of this seemed to be adequate. Finally, a bath solution similar to that used by Seligman was used. It contained sodium chloride, calcium chloride, magnesium chloride, potassium chloride, sodium hypophosphate, sodium bicarbonate and dextrose in physiologic amounts. This solution was well buffered, but required a certain care in mixing and autoclaving to prevent precipitation of insoluble salts.

TABLE 3—Composition of Dialysate (Eighteen Liters of Perfusion Fluid)

Ingredient	Amount, Gm
NaCl.	144
CaCl ₂	1.8
MgCl ₂	1.8
NaH ₂ PO ₄	0.9
Dextrose	27.0
KCl	3.0
NaHCO ₃	18.0

TRANSFUSION OF BLOOD

The next problem was the fact that in a smallish or medium-sized animal there was so much loss of blood into this machine before any was returned that the animal was left with the saline solution in his circulating system and all his blood was out in the apparatus before any was being returned. However, this was overcome by filling the machine with suitable blood for the animal. When this was done, the circulation could be carried on indefinitely without ill effects.

Many of our earlier experiments were carried on in vitro by circulating blood and other solutions through the machine and by placing substances in the circulating fluid which could be detected in the surrounding dialysate (table 4). Next, in a normal animal, with the fluid circulating, 4 Gm of urea were injected, and the rate of removal of this was determined as indicated in table 1. With the tendency of urea to form a closer relationship in the blood of dogs, it was probably not as fair a test of dialysis as might occur in human beings, in whom the urea is separated more readily and is more easily dialyzable. However, this did demonstrate the rate of removal of nonprotein nitrogen substances from a normal animal.

UREMIA IN ANIMALS

The next problem was to produce azotemia in an animal, so that the effectiveness of the apparatus could be assessed under these conditions. Bilateral nephrectomy was observed to involve a number of uncontrollable factors, and the uremia so produced was so severe and associated with such poor resistance in the animal that it did not lend itself to these experiments. A more gradual onset of uremia was desirable and thought to be more comparable to the clinical disease in patients.

The chemical production of oliguria and anuria were investigated, but no completely selective uncomplicating poison which seemed suitable was encountered. Most of the work done on specific renal damage involved the perfusion of the kidney by exposure and cannulation of renal vessels.

TABLE 4.—*Changes in the Blood and Plasma in a Dog During Two Hours of Perfusion by the Artificial Kidney*

Time of Test and Direction of Flow	Blood Nonprotein Nitrogen, Mg /100 Cc.	Plasma Count, Mg /100 Cc.
After 20 min, perfusion, going into apparatus	89.5	410
Fifteen Grams of Urea in Isotonic Solution of Sodium Chloride Added		
After 80 min, going into apparatus	156.2	415
After 80 min, coming out of apparatus	123.6	439
After 2 hr, going into apparatus	98.0	442
After 2 hr, coming out of apparatus	82.4	442

Ligation of ureters was performed on a series of animals, but sudden death, presumably from cardiac arrest as has been described in the literature, was so frequent before dialyzing could be carried out that many of the animals succumbed. Finally, an interesting method of producing uremia was employed. The ureters were transplanted into the small bowel in the hope that there would be sufficient resorption of nonprotein nitrogenous bodies to produce uremia. This took place in a surprisingly short time, and high levels were reached in three or four days, associated with lethargy and diarrhea. The animals, however, maintained their intake of food and fluid, which was not the case in animals with nephrectomy or ureteral ligation.

The study showed that blood can be circulated outside the body and that with a reasonable length of dialyzing tubing moderate amounts of nonprotein nitrogen can be removed in short periods from normal and uremic animals, provided that these animals are not moribund or in a state of severe circulatory depression. The level of nonprotein nitrogen in the blood varies greatly in this state and is a less reliable

guide to the efficiency of the dialyzation than is the nonprotein nitrogen measurable in the dialysate removed during the test run (fig. 4).

It seemed obvious from the experiments as well as from the effects on patients clinically that the level of nonprotein nitrogen substances measured in the blood gave only a poor indication of the effect of such dialysis. Obviously the nonprotein nitrogen substances in the blood stream are not produced there, but are the waste products delivered to this circulating medium from the tissues in which they are produced. This circulating medium, the blood, has the function of carrying these substances to points where they are detoxified, prepared for excretion and finally carried to the kidney where they are excreted from the system. While the level of nonprotein nitrogen substances in the blood may be reduced somewhat, the essential point in treatment is to reduce

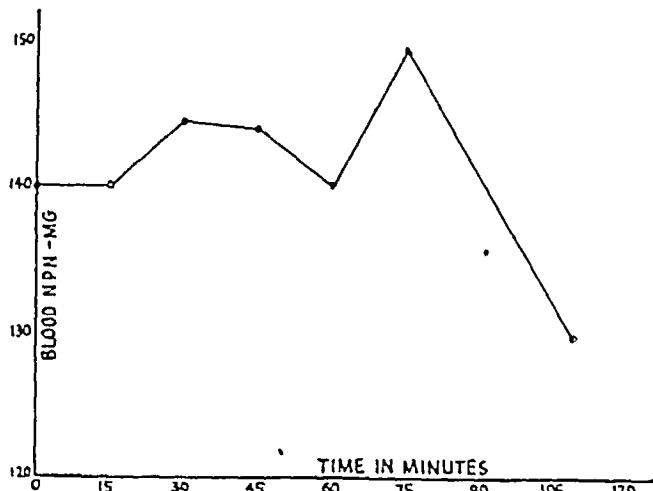


Fig. 4.—Levels of nonprotein nitrogen in dialysis over a period of almost two hours in a male dog weighing 37 pounds (16.8 Kg), with nephrectomy (left kidney) and ligation of the right ureter. The nonprotein nitrogen recovered from the dialysate is also shown.

these and other toxic substances in the vital centers and other fixed tissues. During many of the experiments and in the clinical runs, more nonprotein nitrogen was removed than was contained in the total volume of blood in the animal, and still the level in the blood stream was lowered only slightly. It was obvious, therefore, that there is constant drainage of these substances from fixed tissues into the blood stream one of the functions of which is to transport these substances for disposal.

It seemed of interest, therefore, to investigate this aspect of the problem. For that purpose nephrectomy was performed and the nonprotein nitrogen of the blood and spinal fluid was followed as uremia developed in the animal. When these figures had reached a high level

in these two fluids, the animal was killed and blocks of tissue were immediately frozen and ground up, and estimations of nonprotein nitrogen were made on these by Dr Gornall. The accompanying tables and graphs indicate the results. When the nonprotein nitrogen in the blood reached a certain level, the level in the spinal fluid was above this, and the level of the nonprotein nitrogen substances in the tissue examined was above that level again. This would tend to bear out the point already made that the blood is only a medium of collecting and washing away for disposal of these substances (figs 5 and 6).

When, therefore, 12.97 Gm of nonprotein nitrogen substances were removed from the patient herein reported and readings of the blood showed only a slight depression of the level of nonprotein nitrogen, it was

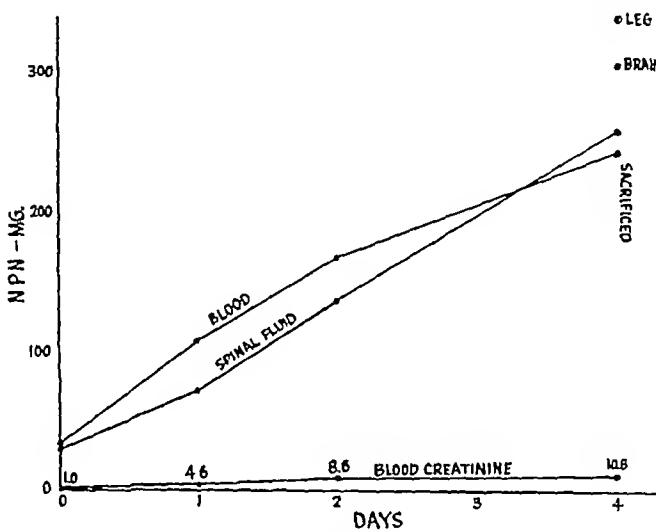


Fig 5.—Graph showing the daily rising of nonprotein nitrogen in the blood and spinal fluid in a female dog that weighed 15 Kg and had undergone nephrectomy (left kidney) and ligation of the right ureter. On the third day the level in the cerebrospinal fluid passed that of the blood. The animal was killed on the fourth day, and assays of tissue showed nonprotein nitrogen in leg muscle 418 mg and brain tissues 301 mg. The levels in the blood and cerebrospinal fluid were about 250 mg.

obvious that the removal was bringing down the level of these toxic substances in the vital fixed tissues of the patient. The proof of this was the clinical improvement of the patient, with diminishing signs of toxemia even though the nonprotein nitrogen in the blood was still at a fairly high level.

From the events observed experimentally and clinically, we think it can be assumed fairly certainly that while nonprotein nitrogen substance can be removed there are other substances also that are removed by this dialyzing system. These substances are probably responsible in large part for severe toxemia and ultimately for death. Proof of

this is the fact that in a normal animal from four to ten times the amount of urea necessary to place the nonprotein nitrogen at a high level can be given without much injurious effect. Probably, therefore, there is another substance responsible for the toxemia. This substance has not been isolated and has not been described or analyzed, but this system offers an excellent method of approach to the study of such substances, as suggested by Abel, Rountree and Turner.²

This work represents only early excursions into a field which offers great prospects for expansion. It might be used therapeutically in the way of removal of toxic substances as well as in the administration of substances which may be beneficial to the patient.

Several runs have been made on clinical patients to test the function of the apparatus. The clinical case which is reported is of considerable

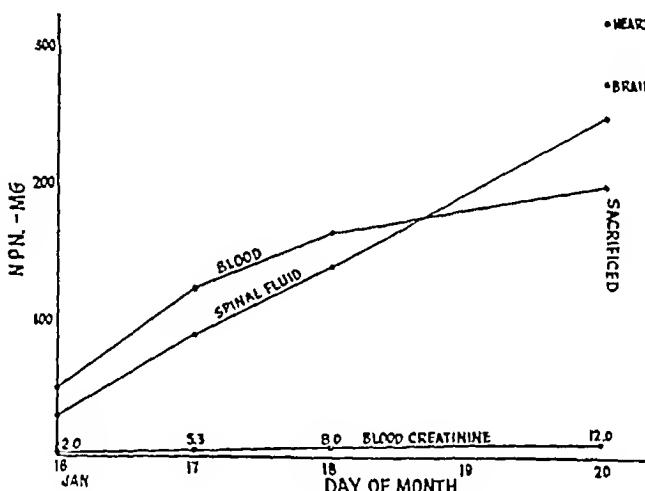


Fig. 6.—Graph showing nonprotein nitrogen levels in the blood and cerebrospinal fluid (250 mg per hundred cubic centimeters) and in leg muscle (345 mg), cardiac muscle (320 mg) and brain tissue (275 mg) following bilateral nephrectomy in a male dog that weighed 12 Kg and had undergone nephrectomy (left kidney) and ligation of a ureter. (These are preliminary reports only.)

significance as regards the function and ability of this apparatus to perform what was intended of it.

REPORT OF A CASE

A patient, 26 years of age, following an attempt at induced abortion had anuria for nine days. During this period the patient was passing about 35 cc. of urine daily and when seen first had uremia. She was comatose, was having mild uremic convulsions, was greatly edematous and was not passing urine. She was seen by the internists, the gynecologists and the genitourologists, all of whom agreed that the case was utterly hopeless, and, in fact, they had given up treatment except for some diathermy which was being applied through the loins.

On this ninth day the patient was attached to the artificial kidney by passing a catheter through the saphenous vein into the inferior vena cava on the right

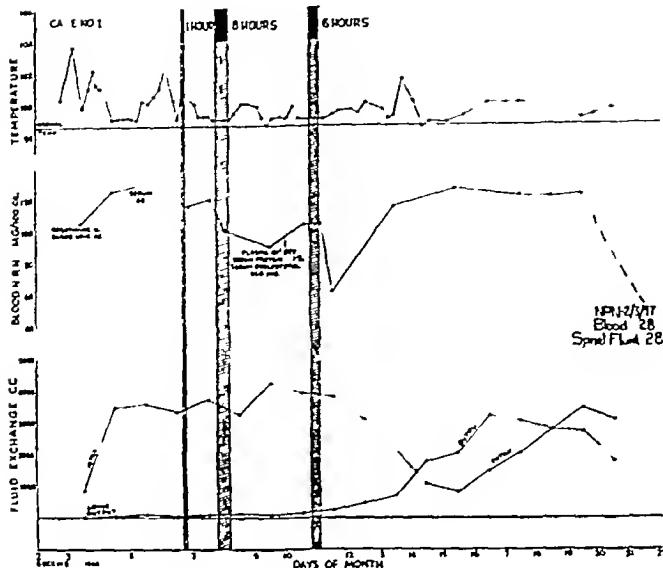


Fig 7.—Graph from the reported clinical case, showing the clinical course preceding, during and after dialysis of the blood with the artificial kidney over a period of twenty-one days in the hospital. The shaded vertical bars on the sixth, eighth and eleventh days show the periods of dialysis with the artificial kidney over a total period of about sixteen hours. The fall to normal of the nonprotein nitrogen on Feb 3, 1947 is indicated.

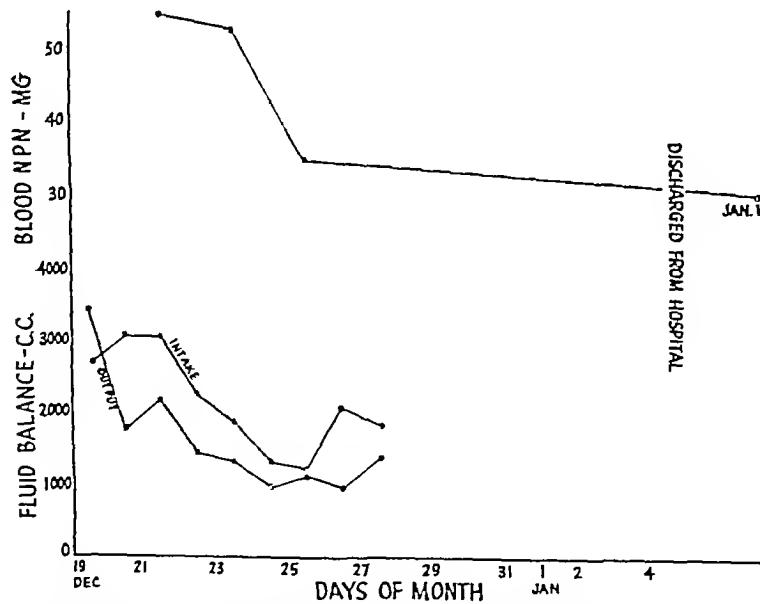


Fig 8.—Graph (continuation of graph in figure 7) showing the later stages of recovery of the patient, with the nonprotein nitrogen back to normal and the water balance again normal.

side and another into the femoral vein on the left. With the machine running for one hour, the patient was moderately improved. The results of the run are shown in figures 7 and 8.

Toward the end of the hour the patient showed some discomfort. She experienced a fairly severe chill. Because of this, because the effects were not known and because of difficulty in following the chemical changes accurately, the dialysis was discontinued at the end of an hour (fig 9). It was shown fairly conclusively on subsequent runs, without any similar ill effects, that probably the trouble was in inadequate washing of the tubing. On all occasions we used new tubing, including rubber tubing throughout the tambour in the pump as well as the dialyzing membrane. On subsequent occasions this was thoroughly washed with distilled water for an adequate period of time and then washed for a short

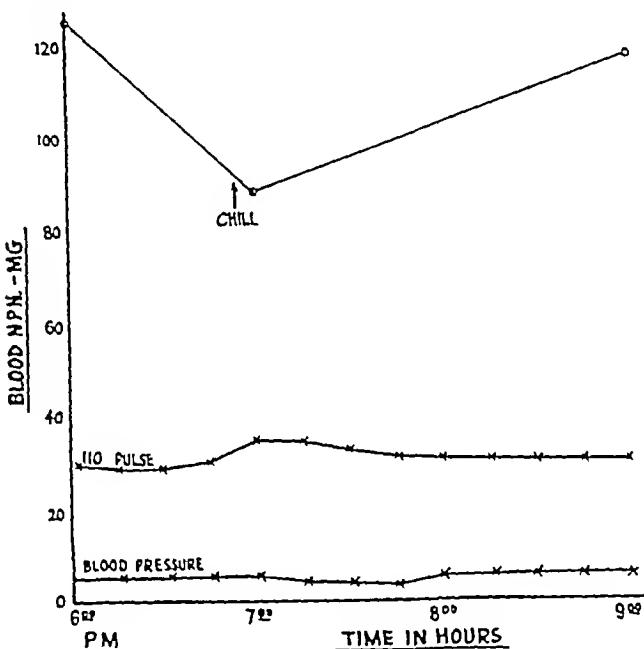


Fig 9.—Graph showing the reduction of nonprotein nitrogen in the blood of the patient during one hour of dialysis (Dec 6, 1946), with the removal of 330 mg of nonprotein nitrogen in the dialysate. Thirty-three feet (about 1,006 cm) of dialyzing tubing was used.

time with blood solution to remove any remaining substances either in the dialyzing membrane or the tubing. On subsequent runs, lasting up to eight hours, there were no ill effects whatever in the form of thermal reactions, changes in respiration, pulse rate, blood pressure or the like.

After the treatment the patient was considerably improved clinically. The next day the patient was fair. The day following that she was much worse again and a run of eight hours was given on the machine. The results of this are shown in figure 10. The patient was greatly improved. There was still passage of only 45 cc of urine. Three days later the patient was again seriously ill and a run of seven hours was given the results of which are shown in figure 11. The clinical improvement of the patient was striking. She was comatose at the beginning of each of these runs on the machine, and at the end the delirium

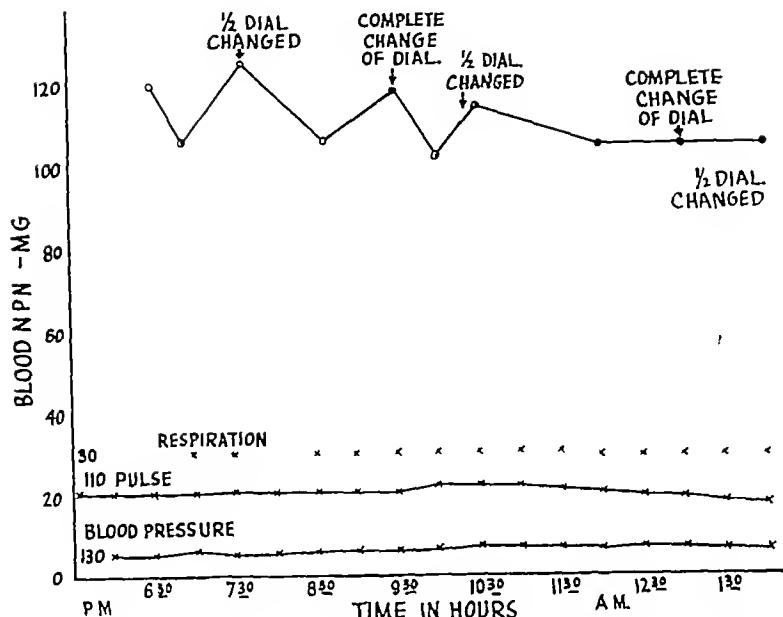


Fig 10.—Graph showing, in the clinical patient, the second run of slightly more than eight hours (Dec 7-Dec 8, 1946) on the machine. The fall in the level of nonprotein nitrogen in the blood following the repeated changing of the dialysate is shown. There was no ill effect on blood pressure, pulse or respiration. There were 6,600 mg of nonprotein nitrogen removed in the dialysate. Thirty-three feet (about 1,006 cm) of tubing was used.

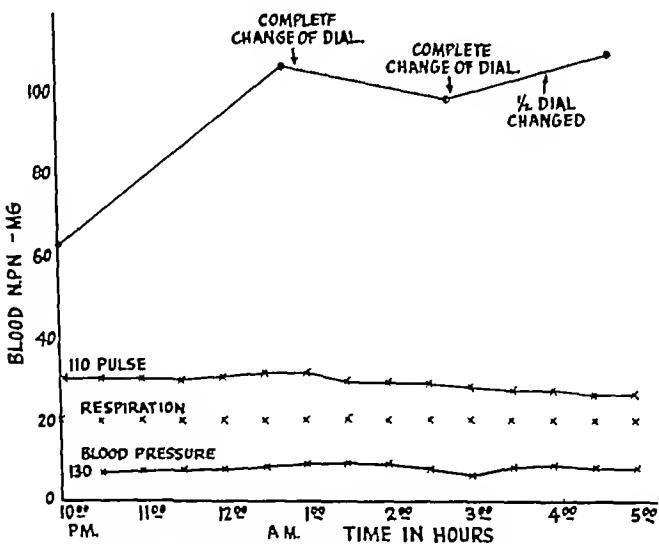


Fig 11.—Graph showing the third run (six and one-half hours, Dec 10-Dec 11, 1946) on the machine. There were 6,040 mg of nonprotein nitrogen removed from the blood during this period. Thirty-one feet (about 945 cm) of tubing was used.

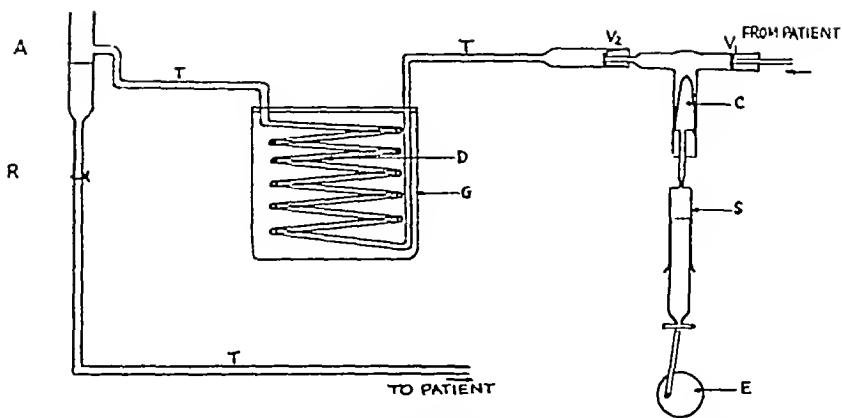


Fig 12.—Schematic drawing of the artificial kidney (not drawn to scale). V_1 and V_2 are valves, C is the condum, S syringe, E eccentric, T rubber tubing, A air trap, R inlet control, D dialyzing membrane and G bath jar



Fig 13.—View of the patient in bed, attached to the artificial kidney

and coma had disappeared. The patient would drink small quantities of fluid, would respond to questions and conversation and stated that she felt much better. In spite of the decided edema, she had some appearance of intelligence.

During the runs on the machine samples of blood, ascitic fluid from the peritoneal cavity and spinal fluid were removed, and determinations of nonprotein nitrogen and other substances were made from these, as indicated on the graph.

After the last dialysis there was a moderate secretion of urine, and the next day there was an enormous secretion of 4,000 cc of urine. Subsequently the patient

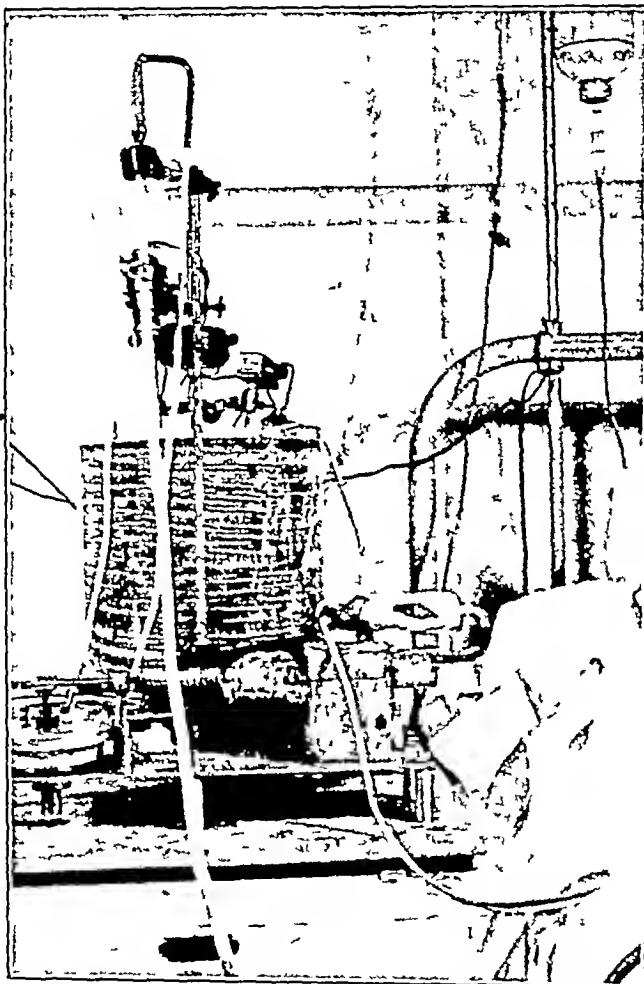


Fig. 14.—The artificial kidney in use on a patient. The glass containing the coil of dialyzing tubing, circulating pump and motor, air trap, heater of the dialysate, stirrer and thermostat are shown.

made a progressive and uninterrupted recovery, and her health returned to normal. During the next two weeks samples of blood and spinal fluid were examined, and these showed a progressive fall of nonprotein nitrogen in both blood and spinal fluid, until on the twenty-fifth day these were both normal. The edema had entirely disappeared. The patient was out of bed and going about and was in normal health. At this stage the gynecologists reported that the fetus was not present in the uterus. While there was no record of its escape, we think that one

cannot assume that the dialyzing apparatus removed it by this means. The patient was in the hospital thirty-three days.

The only remaining abnormality was a lack of concentration as shown in the two hour test. The urine otherwise was normal, and the two hour test showed a concentration only up to 1.012. However, at a later date, as shown on the final point on the chart, on the sixty-first day the nonprotein nitrogen in the blood was 28 mg and in the spinal fluid 28 mg per hundred cubic centimeters, and considerable improvement was demonstrated in the two hour test, as shown in table 5. Here the concentration went up to 1.018, and the diurnal and nocturnal quantities were close to normal. The patient has gone back to her regular work and is in good health.

TABLE 5.—*Results of Two Hour Concentration Test of Urine on the Sixty-First Day Following Recovery*

Time (2/3/47)	Volume, Cc	Specific Gravity	Albumin	Sugar	Microscopic Observations
10 a m	120	1.012	—	—	
12 noon	126	1.010	—	—	
2 p m	69	1.017	—	—	
4 p m	114	1.017	—	—	
6 p m	90	1.016	—	—	
10 p m	246	1.016	—	—	
10 p m to 8 a m	463	1.018	—	—	Occasional white blood cells
Total	1,229*				

Day total 764 and night total 465 cc

SUMMARY

A report is made after a great deal of experimental work, of an artificial kidney or dialyzing membrane which has been used in such a way that it can be applied safely to animals or to human beings. This membrane can be used to remove toxic substances from the blood. With proper buffering of the dialysate, there are no injurious effects as a result of this dialyzing process.

A clinical case of significance is described, in which a cure was effected.

Professor Van Wyke provided the patient whose record of treatment is reported, laboratory space and some chemicals were provided by Prof Andrew Hunter and Dr Allan G. Gornall assisted with nonprotein nitrogen assays of tissue. Some facilities were provided by the Banting Institute. Otherwise this work was carried on with private funds only and without other assistance.

502 Medical Arts Building

DISCUSSION

DR. VICTOIRE DARWIN LESPINASSE, Chicago. My colleagues and I are grateful to Dr. Murray for showing us a practical method of parabiosis. Experimentally, we have tried parabiosis in rats. Those that have been poisoned with mercury bichloride can be assisted over the period of acute renal damage with parabiosis. Dr. Murray's idea of tiding the patient over the period of glomerular damage is well borne out by our experimental work.

MEDULLARY TRACTOTOMY FOR RELIEF OF INTRACTABLE PAIN IN UPPER LEVELS

ALBERT S CRAWFORD, MD

Surgeon-in Charge, Division of Neurological Surgery, Henry Ford Hospital
DETROIT

MEDULLARY tractotomy has already become an established procedure as a method of severing the afferent pain pathways—the spinothalamic tracts. Several surgeons deserve mention as pioneers in developing this procedure. Schwartz and O'Leary¹ reported the first case in 1941 after Sjoquist,² Rowbottom,³ Walker⁴ and Grant, Groff and Lewy⁵ proved the method feasible from their experiences with medullary tractotomy of the descending root of the fifth cranial nerve. White⁶ also reported a case in 1941, pointing out that the incision should be made caudad to the lower end of the olive. Adams and Munro⁷ in 1944 reported 3 cases, in 1 of which a bilateral tractotomy was done in two stages, with survival in all. In his cases, however, the upper level of analgesia for pain was in the upper dorsal region. He apparently felt that it was not feasible to try for a higher level, because of the attending risks resulting from deeper cuts. This may be one reason that more cases have not been reported in which

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb 21, 1947

1 Schwartz, H G, and O'Leary, J L Section of Spinothalamic Tract in Medulla with Observations on Pathway for Pain, *Surgery* **9** 183, 1941

2 Sjoquist, O (a) Studies on Pain Conduction in the Trigeminal Nerve A Contribution to the Surgical Treatment of Facial Pain, *Acta Psychiat et neurol (supp)* **17** 1, 1938, (b) Trigeminal Neuralgia Review of Its Surgical Treatment and Some Aspects of Its Etiology, *Acta chir Scandinav* **82** 201, 1939

3 Rowbottom, G F Treatment of Pain in the Face by Intramedullary Tractotomy, *Brit M J* **2** 1073, 1938

4 Walker, E A L Anatomy, Physiology and Surgical Considerations of the Spinal Tract of the Trigeminal Nerve, *J Neurophysiol* **2** 234, 1939

5 Grant, F C Groff, R A, and Lewy, F H Section of the Descending Spinal Root of the Fifth Cranial Nerve, *Arch Neurol & Psychiat* **43** 498 (March) 1940

6 White, J C Spinothalamic Tractotomy in Medulla Oblongata Operation for Relief of Intractable Neuralgias of Occiput, Neck and Shoulder, *Arch Surg* **43** 113 (July) 1941

7 Adams, R D, and Munro, D Surgical Division of the Spinothalamic Tract in the Medulla, *Surg, Gynec & Obst* **78** 591, 1944

there were attempts to secure an upper level of analgesia in the midcervical region.

Experience with this procedure has led me to believe that it is feasible to try for the upper level of analgesia, at least on one side at a time, and I report herewith 11 cases, in 9 of which unilateral section was done and in 2 of which bilateral section was done at one operation.

REPORT OF CASES

CASE 1—A woman of 40 had intractable pain from an incurable carcinoma, with metastasis to the fifth dorsal spine on the right side. A medullary tractotomy of the left side was done Feb. 7, 1942. The operation was done under local anesthesia, with the patient in the sitting position. A suboccipital exposure on the left side was made through an inverted U-shaped incision. The cut in the side of the medulla was made about 9 mm caudad to the obex to a depth of about 5 mm. The cut was made ventral to the bulge of the descending root of the fifth cranial nerve. There were no special technical difficulties, and the patient stood the procedure well and made a good recovery from the operation. She did have transient hemiplegia (left), which began clearing up the third day and was gone in a month. The upper level of pain algesia was between the second and third cervical segments on the right side. She died of her carcinoma four months postoperatively, having been free of her pain until death.

Comment—I feel that the hemiplegia probably resulted from cutting a little too far caudad and causing some damage to the pyramidal fibers at the decussation.

CASE 2—A man of 40 had abdominal pain from an incurable carcinoma of the colon. Anticipating that the pain was likely to extend upward, a bilateral medullary tractotomy was done Feb. 20, 1942. The operation was done in the sitting position under local anesthesia with a midline incision of the skin. The incisions in the medulla were made at about the level of the obex, about 5 mm deep, with a surface cut of about 3 mm, in front of the eminence of the descending root of the fifth nerve. There was no trouble with bleeding, and the patient stood the procedure well. He moved all of his extremities, and his upper level of analgesia was at the level of the third cervical segment. However, about twelve hours postoperatively hyperthermia developed, he was unable to swallow, and there rapidly developed medullary signs, which did not respond to corrective measures. He died less than twenty-four hours after operation. Postmortem examination showed no hemorrhage and only a minimal amount of edema.

Comment—I felt then that the cut was probably a little too far cephalad and probably a little too deep, involving the vagus nuclei.

CASE 3—A woman of 53 had intractable pain in the left axilla from a metastatic inoperable carcinoma. A medullary tractotomy of the right side was done Oct. 9, 1942, under local anesthesia with the patient in the sitting position. The cut in the medulla was made about as in the previous case, except that it was made about 5 mm caudad to the obex. She made a good recovery, was relieved of her pain and showed an upper pain level at the fourth cervical segment on the left. She had hemiplegia of the right side, which began clearing up by the third postoperative day and was almost gone in six days. She died at her home one month after operation from rapid pulmonary involvement by the cancer. She had been free of her pain until death.

Comment—Here, again, I probably produced some damage to the pyramidal fibers near the decussation.

CASE 4—A man of 40 was suffering from severe intractable pain in the right shoulder and upper extremity from an extensive recurrent sarcoma in the right shoulder. A medullary tractotomy of the left side was done on Nov 29, 1942, under local anesthesia, and using the same technic as in the last case. There were no special technical difficulties. The patient stood the procedure well and was relieved of his pain. The upper level of analgesia to pain was at the fourth cervical segment on the right. There was no weakness of the extremities. He died five months after operation from extensive pulmonary involvement by the cancer, but had been free from pain on the right side.

CASE 5—A woman of 43 had been suffering for about a year from constant intractable pain, associated with scarring and contractures resulting from extensive burns in the left axilla and upper extremity. Inasmuch as the pain persisted in spite of all procedures, I finally advised medullary tractotomy, although there was a strong associated psychoneurotic problem. The procedure was done on the right side, with the same technic as in the 2 previous cases. No paralysis resulted, and it appeared that she was relieved of the pain in her arm and shoulder, but later variable pains developed in other parts of her body which were not related to the medullary section and were psychoneurotic in origin.

CASE 6—A woman aged 66 was suffering from intractable pain in the right shoulder and arm from a metastatic inoperable carcinoma. A medullary tractotomy of the left side was done on Dec 22, 1944, using the same technic as in the previous 3 cases. The patient stood the procedure well and was relieved of her pain until her death at home months later. She showed a transient homolateral weakness for a few days, but she was grateful for her relief of pain.

CASE 7—A woman of 44 had been suffering from intractable pain in the left arm and shoulder from inoperable carcinoma. A medullary tractotomy of the right side was done June 15, 1945, using the same technic as with the others. The results were excellent, and the pain level obtained was at the third cervical segment on the left. No motor impairment resulted. She was freed of her former pain until her death two months later from extensive local and pulmonary involvement.

CASE 8—A man of 60 was suffering from intractable pain of his left arm and shoulder from a destructive lesion of the upper dorsal aspect of the spine and right scapula. A medullary tractotomy of the left side was done Sept 10, 1945. He stood the procedure well and has remained free of his former pain. The level for analgesia was at the fourth cervical segment. There was a transient homolateral weakness, which began clearing up in ten days and disappeared within a month. He is still alive and able to be about. He has taken trips to Mexico and Europe since the operation. The lesion slowly increased in extent for a while, and he had some pain in the left shoulder, but later that disappeared. The final diagnosis of the destructive lesion is uncertain.

CASE 9—A woman of 60 had pain in the high dorsal region from an incurable malignant growth. A medullary tractotomy of the right side was done, the same as in previous cases, on Feb 2, 1946. The patient stood the procedure well, and an upper level of analgesia was obtained at the third cervical segment on the right. A transient homolateral weakness was present for a few days. She remained free of her former pain until her death two months later.

CASE 10—A man of 40 was suffering from intractable pain in the left side of the high dorsal region from an incurable malignant growth. A medullary

tricotomy of the right side was done, the same as in previous cases. The patient stood the procedure well and was relieved of his former pain. He moved all of his extremities well after the operation, and the upper level for pain was at the third cervical segment on the left side. He died two days postoperatively from a slowly developing hemorrhage, which was recognized too late to save his life.

CASE 11.—A woman of 51 years was suffering from bilateral intractable pain from an incurable malignant growth. A bilateral medullary tractotomy was done because I felt that such an operation, done at one sitting, was a feasible procedure. This operation was done on Feb. 5, 1947, in the sitting position and under local anesthesia augmented with sodium pentothal administered intravenously. Because of the latter, the patient did not respond satisfactorily at the time of sensory stimulation, and I cut about as in previous cases, possibly a little more extensively to insure the incision's being deep enough. She stood the procedure well, was able to move all her extremities, talked and swallowed fairly well and had a pain level bilaterally at the second cervical segment. She seemed to be getting along satisfactorily during the first postoperative day, but then there rapidly developed medullary signs which were interpreted as edema. Respiratory failure supervened late on the second postoperative day. She improved when put in the respirator, but died on the seventh postoperative day, with signs of terminal pneumonia. No postmortem examination could be made.

Comment.—It is unfortunate that I was not able to determine whether death came as a result of hemorrhage or secondary degenerative changes from the sections. However, this case demonstrated that a bilateral section is not immediately incompatible with life. From experimental studies, not yet published it would appear that such a procedure is feasible. But it is probable that with bilateral section there is not the margin of safety as with unilateral section. It is probable that I might have been able to cut a little less deeply had she been able to respond more accurately during the cutting.

As to technic, the operations were all done under local anesthesia with the patients sitting up in the neurosurgical chair. With the one-sided cutting a unilateral inverted U-shaped incision was used cutting away the arch of the atlas and enlarging the foramen magnum on that side. Exposure of the side of the medulla up to the level of the inferior olive and obex was accomplished with a little elevation of the lower pole of the cerebellum. The vertebral artery was covered with a thin strip of "cottonoid." Cotton stamps soaked with procaine hydrochloride 1 per cent solution, were held against the medulla, and then the fine hairlike vessels which interfered with exposure were shrunk away with electrocautery. The level of incision into the medulla was determined by the fine rootlets of the tenth and eleventh nerves. The cuts were made caudad to the last of the vagus rootlets and cephalad to the last of the spinal rootlet of the eleventh nerve. It is shown on the diagram of the right side of the medulla (fig. 1). It was a point about 5 to 6 mm. caudad to the obex.

The cutting was done with a small right-angled blade on a long handle set at a 30 degree angle to the coronal plane. This permitted making a small surface cut 2 to 3 mm long. The cutting blade is 4.5 mm long. After the blade had been plunged in once, there was usually no further remonstrance by the patient and he could be tested with a

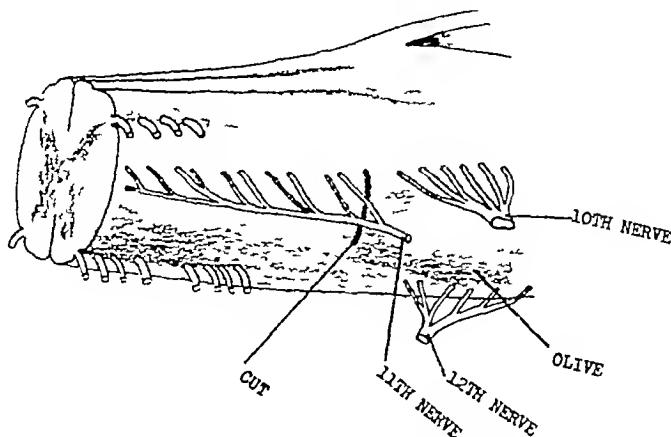


Fig 1.—Right side view of the medulla oblongata

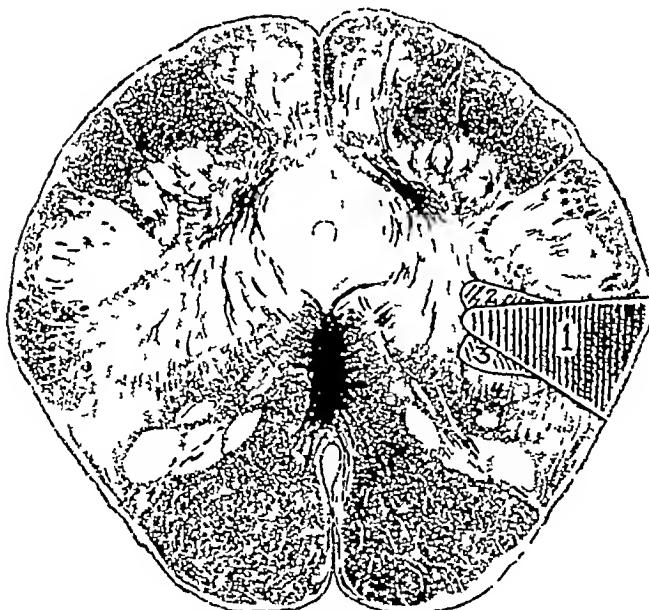


Fig 2.—Transverse section of the medulla oblongata at the lower end of the olive

pm for the upper level of analgesia. If the level was not high enough after this first section (fig 2 [1]), further cuts were made as shown in figure 2 (2 and 3 of the stippled areas), or if a lower level was desired the cuts were made as shown in figure 2 (4). I have most

recently done the secondary cutting (fig 2 [2 and 3] with the blades which are made as hooks (fig 3 [1 and 6]) These permit undercutting without so much surface cutting

There has never been any bleeding from the cutting, except from the minute hairlike vessels on the surface With the blade of the knife one can usually dodge the branches of the posterior cerebellar artery without disturbing them

The dura has always been closed loosely and not made water tight, and one must be careful to obtain absolute hemostasis during closure

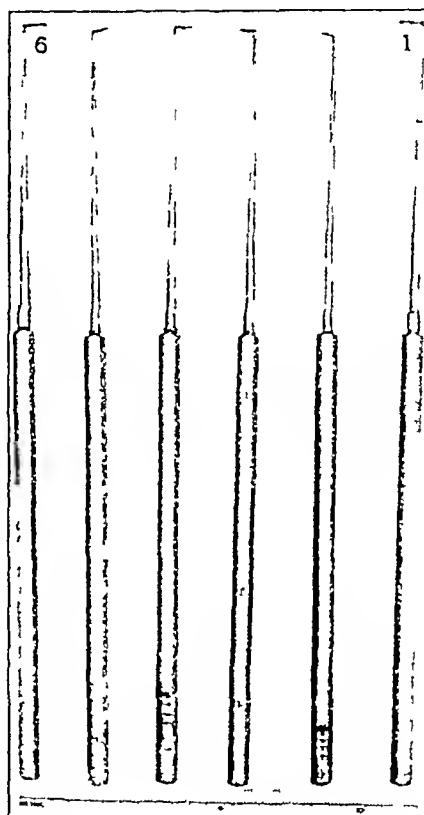


Fig 3—Cutting instruments used

The danger of air embolism must be borne in mind as one of the risks of operating in the sitting position Postoperative bleeding is possibly more likely to occur after this upright approach and probably accounted for 1 or 2 of the 3 deaths

The patients have stood this surgical procedure surprisingly well, considering that they were victims of cancer I have used no special type of head dressing afterward, and they were encouraged to move frequently from side to side

SUMMARY

Nine cases of unilateral and 2 cases of bilateral medullary tractotomy done for intractable pain in the upper part of the torso are reported. All of them resulted in a high level of pain algesia. The 2 patients in whom bilateral medullary tractotomy was done, and 1 in whom unilateral medullary tractotomy was done, died, 1 or 2 of these probably from hemorrhage. There was transient homolateral paralysis in 5 cases. I feel that this can be avoided by cutting only in the areas which are shown stippled in the diagram (fig 3) and at the proper site for section (fig 1) and by avoiding postoperative hemorrhage.

I report these cases mainly to show that the procedure is feasible and with the hope that it will stimulate others to use it to relieve patients with intractable pain of the shoulders and lower cervical regions. With further experience it is believed that bilateral section at one sitting may also be feasible.

ACUTE APPENDICITIS

An Analysis of Eight Hundred and Seventy-Eight Cases at St. Luke's Hospital, Chicago

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AND

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CHICAGO

APPENDICITIS as a clinical entity, has been recognized since 1886, when Fitz,¹ of Boston, coordinated the theories of inflammatory disease in and about the cecum. He originated the term "appendicitis" and described the clinical picture, placing particular emphasis on its early diagnosis and treatment. Among the pioneers in the development of the technic for the removal of the appendix were Sands, listed by Ficarra,² McBurney,³ McArthur⁴ and Murphy.⁵ Sands was among the first to attempt drainage of an appendical abscess. McBurney, in 1894, reported the technic of the muscle-splitting incision, advocating its use exclusively for nonsuppurative, chronic or interval appendicitis. Mc Arthur had then been using the same incision for over three years. Mc Arthur advocated its use in all types of appendicitis, including fulminating types of appendical infection. The mortality rate resulting from acute appendicitis prior to the adoption of chemotherapeutic measures was reported by various authors as 4.5 to 5 per cent. Approximately two thirds of all deaths resulting from peritonitis in the United States

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From the Departments of Surgery, St. Luke's Hospital and the University of Illinois College of Medicine

1 Fitz R H Perforating Inflammation of the Vermiform Appendix, with Special Reference to Its Early Diagnosis and Treatment Also, Tr A Am Physicians 1 107-144 (June) 1886

2 Ficarra B J American Pioneers in Abdominal Surgery, Am J Surg 64 282-286 (Feb) 1944

3 McBurney, C The Incision Made in the Abdominal Wall in Cases of Appendicitis with a Description of a New Method of Operating, Ann Surg 20 38-43 (Aug) 1894

4 Mc Arthur L L Choice of Incisions of Abdominal Wall, Especially for Appendicitis Chicago M Reorder 7 289-292 (Nov) 1894

5 Murphy J B Appendicitis, with Original Report, Histories and Analyses of One Hundred and Forty-One Laparotomies for that Disease Under Personal Observation J A M A 22 302-308 (March 3) 1894

followed acute appendicitis with perforation at that time. The overall mortality rate in acute appendicitis is on the decline. However, the mortality rate in cases of acute appendicitis with perforation has shown no great improvement. This mortality rate is reported as 5 to 17 per cent. These factors have prompted a further analysis of acute appendicitis at St. Luke's Hospital as well as the factors contributing to death from acute appendicitis.

FACTORS IN THIS STUDY

This study represents a series of 878 consecutive and unselected cases of acute appendicitis occurring at St. Luke's Hospital during the period 1939 through 1945. The patients were residents of the Chicago area and represent a cross section of the patients seen in this community. The patients included in this series were all operated on, and the appendix was observed to be acutely inflamed or the source of an abscess. In each instance microscopic confirmation of appendical disease was reported by the pathologist. Cases in which the disease was reported by the surgeon and the pathologist as "subacute," "chronic," "interval" or "chronic mechanical" are not included in this report. The previously reported series over the period 1932 to 1939 by one of us (E. Lee Strohl) from St. Luke's Hospital⁶ will be compared with this series.

Each case analyzed has been placed in one of three groups: (1) acute appendicitis without rupture, a condition in which there was no localized pus or perforation present at the time of operation and the inflammatory process was confined to the appendix; (2) acute appendicitis with perforation, a condition in which the appendix was described by the surgeon and the pathologist as perforated and localized or diffuse peritonitis was present at the time of operation; (3) appendical abscess, in which a well localized area of pus was observed at the time of operation. We believe that the terms spreading peritonitis, diffusing peritonitis and local peritonitis are confusing as criteria for a statistical survey of this type. These terms may be inaccurate, since it is difficult at operation to determine the extent of peritonitis in any given case without abdominal exploration. Exploration is not justified in the presence of acute appendicitis. One disadvantage to the use of these three main groups is that, occasionally, cases of severe appendicitis with gangrene and peritonitis will fall in the "acute unruptured" group, because no gross or microscopic evidence of perforation was noted. Peritoneal culture as a criterion of spread of infection beyond the appendix was not used, because the culture had not been obtained in each instance.

⁶ Strohl, E. L. Acute Appendicitis Analysis of the Records of Three Hundred Cases, Illinois M J 74 171 (Aug) 1938

ANALYSIS OF CASES

Age—Two hundred and twenty-four cases occurring in the second decade of life was the greatest number occurring in any age group (table 1), while there were 222 cases in the third decade and 149 in the fourth decade. Thus, in the second, third and fourth decades there were 599, or 67.8 per cent, of the total series. The average age of all patients included in this series was 28.5 years. The greatest number of perforated appendixes also occurred in the second, third and fourth decades (53, or 55 per cent, of all cases with perforation).

It is interesting to note in our series the similarity in the pattern of the disease in children under 5 years of age and in patients over 70 years of age. Of 22 cases in children under 5 years of age there were 5 with perforation and 2 with abscesses, whereas in 18 cases in patients past 70 years of age there were 6 with perforation and 4 with abscesses.

TABLE 1—*Age Incidence*

Pathologic Condition	0-5 Yr	5-10 Yr	10-20 Yr	20-30 Yr	30-40 Yr	40-50 Yr	50-60 Yr	60-70 Yr	Over 70
Acute appendicitis without rupture	15	52	207	202	118	80	84	9	8
Acute appendicitis with perforation	5	5	12	14	10	20	10	6	6
Appendical abscess	2	3	5	6	12	10	7	7	4
Total	22	60	224	222	140	110	61	22	18

TABLE 2—*Sex Distribution*

Sex	0-5 Yr	5-10 Yr	10-20 Yr	20-30 Yr	30-40 Yr	40-50 Yr	50-60 Yr	60-70 Yr	Over 70	Total
Male	14	39	102	107	83	70	88	12	10	474
Female	8	22	122	116	63	40	13	10	8	404

Sex—In this series there was only a slight predominance in the number of cases occurring in male patients. Of 878 patients, 474 (54 per cent) were male and 404 (46 per cent) were female (table 2). (This study was made during war years.)

Classification—The number of cases of acute appendicitis without rupture was 725, or 82.6 per cent (table 3). The number of cases of acute appendicitis with perforation was 97, or 11 per cent. In 56 cases, or 6.4 per cent, an abscess was observed at operation.

Mortality—During the period of 1932 to 1937, 9 deaths in 300 consecutive cases, a mortality rate of 3 per cent, were reported from St. Luke's Hospital.⁶ During the period 1937 to 1939, there were 10 deaths in 519 cases, a mortality rate of 1.92 per cent, reported from St. Luke's hospital.⁷

⁷ Strohl, E. L.: Appendectomy by the Muscle-Splitting Technic, *S. Clin. North America* 22:1-8 (Feb.) 1942.

There were 13 deaths, following surgical intervention, in the present series of 878 cases. This represents an over-all mortality rate of 1.48 per cent. All deaths occurring after operation for acute appendicitis are included in this study. Two of these deaths occurred from apparent extra-abdominal causes and are included in the 13 deaths (table 4).

There were 4 deaths following the removal of an unruptured appendix in the acute stage of inflammation, a mortality rate of 0.55 per cent. As would be expected in the group with acute appendicitis in which there was perforation, there were 8 deaths in 97 cases, a mortality rate of 8.25 per cent. This was the highest mortality rate of any of the three groups. There was 1 death in the 56 cases of appendical abscess, a mortality rate of 1.78 per cent.

TABLE 3—Classification

Pathologic Condition	Number of Cases	Percentage
Acute appendicitis without rupture	725	82.6
Acute appendicitis with perforation	97	11.0
Appendical abscess	56	6.4
Total	878	100.0

TABLE 4—Mortality

Pathologic Condition	Number of Cases	Number of Deaths	Mortality Percentage 1939 Through 1945
Acute appendicitis without rupture	725	4	0.55
Acute appendicitis with perforation	97	8	8.25
Appendical abscess	56	1	1.78
Total	878	13	1.48

Analysis of Deaths.—The youngest patient that died was 2 years of age, and the oldest was 80 years of age. Eight of the deaths occurred in the fifth and sixth decades, the average age being 42.3 years. Four deaths occurred after removal of an unruptured appendix with acute inflammation. In 2 of this group generalized peritonitis developed, as observed at autopsy. One of the patients was an 80 year old diabetic person, who died of a massive pulmonary embolus ninety-six hours after operation. Autopsy revealed the peritoneum to be free of infection. The remaining death in the group in which the appendix was unruptured was that of a 49 year old man, who died suddenly twelve hours after operation. The cause of death was undetermined.

In the group with acute appendicitis with perforation there were 8 deaths. The patients ranged in age from 3 to 58 years. All deaths

were attributed directly to generalized peritonitis with paralytic ileus, and in 1 instance there was concomitant uremia. Five of the 8 patients in this group had taken a cathartic or an enema shortly after the onset of their abdominal symptoms. Two of this group had purged themselves with both magnesium sulfate and enemas.

The single death in the group with appendical abscess was that of a boy of 2 years. Symptoms were present for two weeks prior to admis-

TABLE 5—*Causes of Death*

Case No	Sex	Age	Type of Pathologic Condition	Duration of Symptoms	Treatment with Sulfonamide Drugs		Cause of Death	Catharsis Used	Autopsy
					Yes	No			
1	M	40	Acute appendicitis without rupture	24 hr	Yes	Yes	Generalized peritonitis	Enema	Yes
2	F	50	Acute appendicitis without rupture	72 hr	Yes	No	Pulmonary embolus	None	Yes
3	M	29	Acute appendicitis without rupture	24 hr	None	No	Generalized peritonitis	None	Yes
4	M	49	Acute appendicitis without rupture	48 hr	None	No	Undetermined 12 hr after operation	None	No
5	M	66	Acute appendicitis with perforation	36 hr	None	Yes	Generalized peritonitis	Saline laxative	No
6	M	49	Acute appendicitis with perforation	48 hr	Yes	Yes	Generalized peritonitis	Magnesia magma	No
7	F	27	Acute appendicitis with perforation	36 hr	None	No	Generalized peritonitis	Magnesium sulfate, enema	No
8	M	53	Acute appendicitis with perforation	48 hr	None	Yes	Generalized peritonitis	Magnesium sulfate, enema	Yes
9	M	58	Acute appendicitis with perforation	48 hr	Yes	Yes	Generalized peritonitis	None	Yes
10	M	56	Acute appendicitis with perforation	48 hr	Yes	Yes	Generalized peritonitis	None	No
11	F	3	Acute appendicitis with perforation	24 hr	Yes	Yes	Generalized peritonitis	None	No
12	M	49	Acute appendicitis with perforation	28 hr	Yes	Yes	Generalized peritonitis	Oastor oil	No
13	M	2	Appendical abscess	2 wk	Yes	Yes	Generalized peritonitis	Magnesia magma repeatedly	No

sion to the hospital, and the child was dehydrated and septic. A mass was palpable in the right lower quadrant of the abdomen. At operation an abscess was drained, without attempt at appendectomy, since the appendix was not easily accessible. The patient died eight hours after operation.

Duration of Symptoms.—The duration of symptoms was determined from the onset of symptoms until admission to the hospital. The period of time that had elapsed prior to admission varied in this group of deaths from twenty-four hours to two weeks. The average elapsed time prior to

hospitalization was sixty-seven hours. This compares closely with the elapsed time in the cases reported by Reid and Montanus⁸ from the Cincinnati General Hospital, in which there was a delay in hospitalization of sixty-four and nine-tenths hours.

Chemotherapy—Sulfonamide drugs were used intraperitoneally and parenterally in the majority of the cases of acute appendicitis with perforation and in appendical abscess since the latter part of 1940 at St Luke's Hospital. It would appear that the sulfonamide drugs were helpful in reducing the morbidity, although there has been no decided reduction of mortality indicated by comparison of present figures at St Luke's Hospital with those of the period prior to use of sulfonamide drugs. Statistically, the effect of sulfonamide drugs would be shown only in the over-all mortality rate, inasmuch as there was no control series. Analysis of the deaths reveals that the sulfonamide drugs were used, in dosages considered adequate, in 7 of the 13 fatalities. These

TABLE 6—*Yearly Mortality*

Year	Number of Cases	Deaths	Percentage Mortality
1939	144	3	2.0
1940	141	2	1.4
1941	128	2	1.5
1942	130	8	1.5
1943	109	1	0.9
1944	110	2	1.8
1945	116	0	0

figures, however, fail to reflect the number of cases of severe peritonitis in which there was recovery and in which the drug was undoubtedly effective.

The mortality rates for each year are listed in table 6, showing a 2 per cent mortality in 1939 which decreased to 0.9 per cent in 1943 and increased to 1.8 per cent in 1944. During 1945, there were no deaths in 116 cases in which there was surgical treatment at St Luke's Hospital. Antibiotic drugs were not used in this series of cases.

Aycock and Farris⁹ reported a substantial decrease in mortality rate, from 5.2 per cent over a four year period when sulfonamide drugs were not used to 1.2 per cent during the period 1940 to 1944 when the sulfonamide drugs were employed. In the cases of acute appendicitis with perforation the mortality rate was reduced from 31 per cent to 10.4 per cent concomitant with chemotherapy.

⁸ Reid, M. R., and Montanus, W. P. Appendicitis. An Analysis of 1,153 Cases at the Cincinnati General Hospital, J. A. M. A. **114**: 1307-1311 (April 6) 1940.

⁹ Aycock, T. B., and Farris, E. M. Appendicitis. The Possible Effects of Sulfonamide on Mortality, Ann. Surg. **121**: 710-717 (May) 1945.

Incision.—The McBurney-McArthur incision was used almost without exception in this series of cases. In the few instances in which other incisions were employed the choice of another incision was made because the diagnosis was in error or indefinite.

TABLE 7.—Reported Mortality Rates

Author Reporting	Acute Appendicitis Without Rupture		Acute Appendicitis With Perforation		Appendical Abscess		Total	
	Number of Cases	Mortality Percentage	Number of Cases	Mortality Percentage	Number of Cases	Mortality Percentage	Number of Cases	Mortality Percentage
Reid and Montanus, ⁸ Cincinnati General Hospital (1934 to 1938)	533	1.0	209	17.2	129	10.0	921	6.0
Green and Watkins, ¹⁰ Cleveland City Hospitals (1930 to 1941)	14,605	0.94	3,216	18.6	1,550	12.6	10,899	4.8
Cutler and Hoerr, ¹¹ Peter Bent Brigham Hospital (1913 to 1911)	1,604	1.2	339	17.1	247	7.3	2,192	4.4
Stasford and Sprong, ¹² Johns Hopkins Hospital (1931 to 1939)	825	0	100	14.2	233	7.1	1,317	3.0

TABLE 8.—Reported Mortality with Use of Sulfonamide Drugs

Author Reporting	Acute Appendicitis Without Rupture		Acute Appendicitis With Perforation		Appendical Abscess		Total	
	Number of Cases	Mortality Percentage	Number of Cases	Mortality Percentage	Number of Cases	Mortality Percentage	Number of Cases	Mortality Percentage
Aycock and Farris, ⁹ Baltimore City Hospital (1910 to 1944)	418	0	55	5.7	27	8.0	300	1.2
Mueller ¹³ Roosevelt Hospital, New York (1910 to 1944)	573	0	110	0.91	56	3.57	739	0.40
St. Luke's Hospital, Chicago (1939 to 1945)	725	0.55	97	8.25	56	1.78	878	1.48

Comment.—There has been slight improvement in the over-all mortality rate for this seven year series, as compared with the previously analyzed seven year series. The improvement is not as great as some authors have reported since the advent of chemotherapy.

Prior to the general use of chemotherapy, Reid and Montanus⁸ reported an over-all mortality rate of 6.0 per cent (1934 to 1938), Green

and Watkin¹⁰ 4.8 per cent (1930 to 1941), Cutler and Hoerr¹¹ 4.4 per cent (1913 to 1941) and Stafford and Sprong¹² 3.6 per cent (1931 to 1939). Authors reporting since the sulfonamide drugs have been generally used, list somewhat lower mortality rates Aycock and Farris⁹ 1.2 per cent (1940 to 1944), and Mueller¹³ 0.40 per cent (1940 to 1944). Stafford and his co-workers¹⁴ in 145 cases of appendical peritonitis in 1942 reported a mortality of 3.4 per cent (table 8).

SUMMARY AND CONCLUSIONS

In a series of 878 cases of acute appendicitis at St Luke's Hospital during 1939 to 1945, 725 were without rupture, 97 were accompanied with perforation and peritonitis and in 56 abscesses had formed. Criteria are given for the classification of acute appendicitis without rupture, acute appendicitis with perforation and appendical abscess. Stress is laid on the importance of pathologic examination of the appendix in order to obtain accurate statistics.

The over-all mortality rate of 1.48 per cent is broken down as follows: 0.55 per cent in acute appendicitis without rupture, 8.25 per cent in acute appendicitis with perforation and 1.78 per cent in appendical abscess. An analysis of the deaths revealed that 11, of a total of 13 patients, died as a direct result of progression of the appendical infection or of specific complications. One patient died of pulmonary embolism. The cause of 1 death was undetermined. Delay in operation continued as a major factor in death in the cases of acute disease with perforation, and the average elapsed time from onset of symptoms until admission to the hospital was sixty-seven hours. The over-all mortality rate of 1.48 per cent at this time, as compared with 1.92 per cent in 1939, reflects little or no evidence that the sulfonamide drugs have been a significant factor in the reduction of mortality in acute appendicitis at St Luke's Hospital.

122 S Michigan Avenue

10 Green H W, and Watkins, R M Appendicitis in Cleveland, Surg, Gynec. & Obst. **83** 5-613-624 (Nov.) 1946

11 Cutler, E C, and Hoerr, S O Acute Appendicitis A Twenty-Five Year Study, J Michigan M Soc **41** 203-210 (March) 1942 Hoerr, S O Mortality Factors in Acute Appendicitis, Surgery **18** 305-317 (Sept.) 1945

12 Stafford, E S, and Sprong, D H, Jr Mortality from Acute Appendicitis in Johns Hopkins Hospital, J A M A **115** 1242-1245 (Oct. 12) 1940

13 Mueller, R S The Local Use of Sulfonamide in the Treatment of Acute Appendicitis, Ann Surg **122** 625-630 (Oct.) 1945

14 Stafford, C E, Besevick, J, and Deeb, P H Evaluation of the Sulfonamides in Treatment of Peritonitis of Appendical Origin, Am J Surg **64** 227-234 (May) 1944

DISCUSSION

DR. OTTO W. NIEMEIER, Hamilton, Ontario, Canada I would like to compliment Dr Strohl on his excellent paper on appendicitis I feel that this subject warrants a few minutes of discussion He does not present as remarkable a drop in mortality as is shown in some sections A more progressive drop has occurred in the Hamilton General Hospital, from 5 per cent to 4 per cent and finally to 0.5 per cent I was interested to know that it rose in Dr Strohl's series from 0.9 to 1.48 per cent, which is not a remarkable rise but bears out something that I believe is occurring I believe that this remarkable improvement has led to a feeling of complacency on the part of the public and perhaps the medical profession in regard to acute appendicitis I have the impression that more cases with perforation and cases of late disease with prolonged morbidity are being seen The necessity for early operation in this condition should continue to be stressed.

In regard to the reduction in mortality, I believe that there are other factors as important as chemotherapy I believe that suction drainage has been used more lately, and to that I attribute a considerable improvement in the hands of surgeons I think that in postgraduate teaching one should impress students with the necessity for early operation in acute appendicitis in spite of these weapons which make it seem so safe

EXPERIENCES WITH THE BLALOCK OPERATION FOR TETRALOGY OF FALLOT

F D DODRILL, M.D
DETROIT

THE BLALOCK operation¹ is the anastomosis of one of the systemic arteries arising from the aortic arch to either the right or the left pulmonary artery. This may be done by either an end to side or an end to end method of suture. The operation is indicated in cases of congenital pulmonary stenosis or atresia of the pulmonary orifice.

Although pure pulmonary stenosis does occur, most children with this anomaly also have the associated defects of dextroposition of the aorta, interventricular septal defect and right ventricular enlargement. This is known as tetralogy of Fallot. The disabling factor in the malformation is the pulmonary stenosis, which prevents sufficient blood from reaching the lungs to permit normal oxygenation of the blood.

The diagnosis of pulmonary stenosis is made on the presence of noticeable cyanosis, clubbing of the fingers and toes, increased red blood cell count and the appearance of the heart in roentgenologic and fluoroscopic examination. Great emphasis is placed on the fluoroscopic examination, there being greatly diminished or absence of pulsations of the pulmonary arteries at the hilus of the lung. A systolic murmur, heard best at the level of the second or third anterior interspace to the left of the sternum, may or may not be present. The heart is not enlarged except during the terminal stages of the disease when some increase in its size may take place.

Thirteen operations have been performed. This includes all cases in which an incision was made. One patient was operated on the second time, there being 12 patients in this group. In all cases the diagnosis was confirmed by the observation of a small pulseless or nearly pulseless pulmonary artery. In 1 patient no pulmonary artery was present, there being a network of small collateral arteries about the pulmonary hilus, which probably arose from the bronchial artery. An anastomosis was, of course, not performed in this patient.

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb 21, 1947

¹ Blalock, A., and Taussig, H. B. Surgical Treatment of Malformations of the Heart in Which There Is Pulmonary Stenosis or Pulmonary Atresia, 128 189 (May 19) 1945 Blalock, A. Ann Surg 124 879 (Nov) 1946

A curved intramammillary incision was made in all cases, the third anterior interspace being entered. Either the right or the left pleural space was entered, depending on the position of the aortic arch. In this malformation the aortic arch may be on either the right or the left side. An approach was made opposite to the side on which the arch was present. The position of the arch was determined by fluoroscopy of the chest as well as by the administration of barium by mouth in order to determine which side of the esophagus was indented by it, the left arch indenting the left side and the right arch indenting the right side of the esophagus in the anteroposterior view.

All patients have been operated on with an experienced anesthetist administering the anesthetic agent. Cyclopropane has been used in all cases with an endotracheal tube in place. The respiratory act has

TABLE 1—*Age, Sex, Systemic Vessel Used and the Clinical Result*

Case No	Patient	Age, Yr	Sex	Systemic Vessel Used	Result
1	N J	9	M	Left common carotid.	Excellent
2	C H	5	M	Left common carotid	Excellent
3	P S	12	F	Left common carotid	Died
4	R D	4½	M	Right common carotid	Excellent
5	P P	7	M	(No anastomosis)	No change
6	P P	7	M	(No anastomosis)	No change
7	D B	11	M	Right subclavian	Excellent*
8	P H	5	M	No anastomosis	Died
9	P O	5	F	Right common carotid	Excellent
10	A S	4	F	Right subclavian (end to end)	Died
11	L G	12	F	Left subclavian	Fair
12	W Z	3½	M	Right subclavian (end to end)	Good
13	O M	3½	M	Right subclavian	Not yet determined (operation only recent)

* Cerebral thrombosis developed in this patient, but he recovered.

been entirely controlled or, at least, assisted. This method has permitted the operation to be performed in a comparatively quiet field. One patient in this group, however, was in such precarious condition that the lung could not be permitted to collapse without serious respiratory difficulty. It was kept almost fully inflated, and the field of operation was packed off to permit the operation to be completed. The technic of anastomosis which has been described by Dr. Blalock has been used, except in a few cases in which the pulmonary artery was so small and, therefore, the incision in it so small, that interrupted sutures instead of a continuous suture were used.

Table 1 shows the systemic artery used. In 5 patients the common carotid artery was used for the anastomosis, and in the remaining patients the subclavian artery was used. The innominate artery has not been used in any patient. When an artery the size of the innominate was desired, it was thought to be too short to reach to the pulmonary

artery. Therefore, the subclavian artery was ligated and divided near its origin, and sufficient length of the common carotid was developed so as to reach to the point of anastomosis. By such a method the full volume of blood passing through the innominate artery reaches the lungs. An end to end method of suture was used in 2 patients, the remaining anastomoses being carried out by the end to side technic.

The clinical results are also shown in table 1. By an excellent result is meant that the cyanosis disappeared, the red blood cell count became decidedly decreased, the clubbing of the fingers and toes receded or disappeared and the physical reserve of the patient was greatly improved. The arterial oxygen saturation has increased in all patients who survived the operation. One patient was unusual in this respect. The patient in case 9 showed an arterial oxygen saturation of 27.0 volumes per cent before the common carotid was anastomosed to the right pulmonary artery. Two weeks following this procedure the arterial

TABLE 2.—List of Fatal Cases, Showing the Vessel Used, the Red Blood Cell Count, the Hematocrit Reading and the Cause of Death

Case No	Systemic Artery Used	Red Blood Cell Count	Arterial Oxygen Saturation, Vol %	Hematocrit Reading	Cause of Death
3	Left common carotid.	9.3	16.8	93	Shock
8	(No anastomosis)	12.0	22.8	92	Cardiac insufficiency
10	Right subclavian (end to end)	11.5	21.7	100	Pulmonary hemorrhage

oxygen saturation was reported as 95.0 volumes per cent, the usual figure for a normal person. The test has been repeated and verified as the correct determination. In all probability this patient had a pure pulmonary stenosis, without the associated defects.

In table 2 the fatal cases are tabulated showing the systemic vessel used, the red blood cell count, the arterial oxygen saturation, the hematocrit reading and the cause of death. It is seen that in these fatal cases the red blood cell count and the hematocrit readings were unusually high, the hematocrit reading in case 10 being reported as 100. In other words, there was no separation of cells from plasma. Death in the first fatal case is listed as due to shock. The anastomosis had been completed, although the blood pressure or pulse could not be obtained. The child died two hours later, without having regained consciousness. The patient in the second fatal case died before the anastomosis was begun. Death was thought to be due to cardiac insufficiency, as the heart gradually slowed and finally ceased to beat. Post-mortem examination showed an atresia of the pulmonary orifice, the entire pulmonary circulation reaching the lungs through a small patent ductus arteriosus. The third fatality was due to pulmonary hemor-

rhage, which occurred four hours after the completion of the operation. This is the only patient in this group who received heparin or dicumarol. Two hours after the operation the temperature was elevated to 102 F., there was some twitching on the opposite side of the body and the patient had not rallied. Believing that cerebral damage was occurring, the initial calculated dose of heparin was given. Two hours later there was a severe pulmonary hemorrhage, and, even though intratracheal suction was quickly carried out, the patient died.

In the patients who survived the procedure there have been few complications.² As a rule the patient dies soon after the operation or survives. One patient experienced acute laryngeal edema requiring an

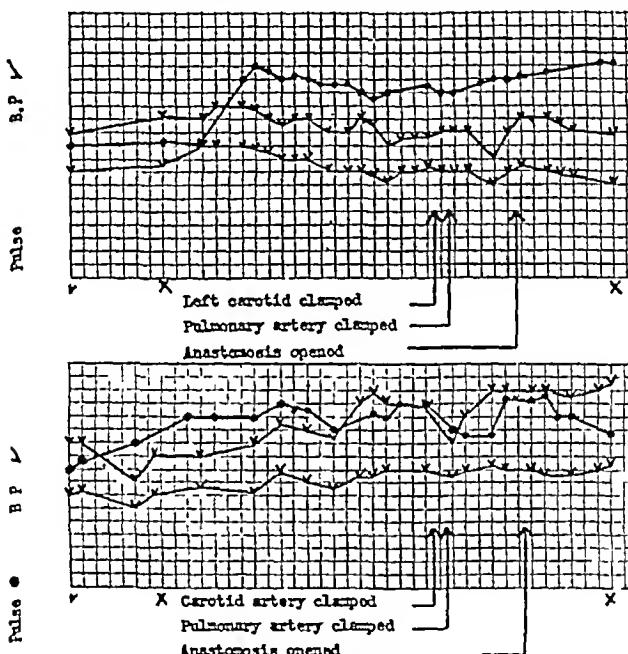


Fig 1.—The upper chart shows blood pressure during the course of anastomosis of the carotid and pulmonary arteries (technic carbon dioxide absorption, endotracheal intubation). No significant fall in blood pressure occurred. Cyclopropane and oxygen were used, and the result was good. The lower chart shows no significant fall in blood pressure in anastomosis of the carotid and pulmonary arteries (technic carbon dioxide absorption, endotracheal intubation). Cyclopropane and oxygen were used, and the result was good.

emergency tracheotomy. Another patient had a pneumothorax after the operation, and the lung could not be reexpanded for a period of three weeks, even though constant suction to the lung by means of a needle in the chest was maintained. It was thought that the visceral pleura had been torn or severely damaged. The occurrence of sero-sanguinous fluid in the pleural space has been so common that it is not

² Harmel, M. H., and Lamont, A. Anesthesiology 7:477 (Sept.) 1946.

regarded as a complication. Aspiration is resorted to at the least sign of fluid in physical examination. Usually a sufficient amount of fluid is obtained to warrant the procedure. In 1 patient definite cerebral thrombosis developed, but the patient survived and has now almost completely recovered. The subclavian artery was used for the transplant, and the common carotid was not disturbed. Apparently periods of hypotension during the procedure adds greatly to the operative risk. In figure 1, which is the anesthesia charts, there is seen in the upper chart a slight drop in blood pressure when the carotid was clamped and a slight rise when the pulmonary artery was clamped. However, there is no great change in either direction. The lower chart also shows that no significant change has taken place. One can predict that such a patient will, as a rule, do well in the postoperative period. On

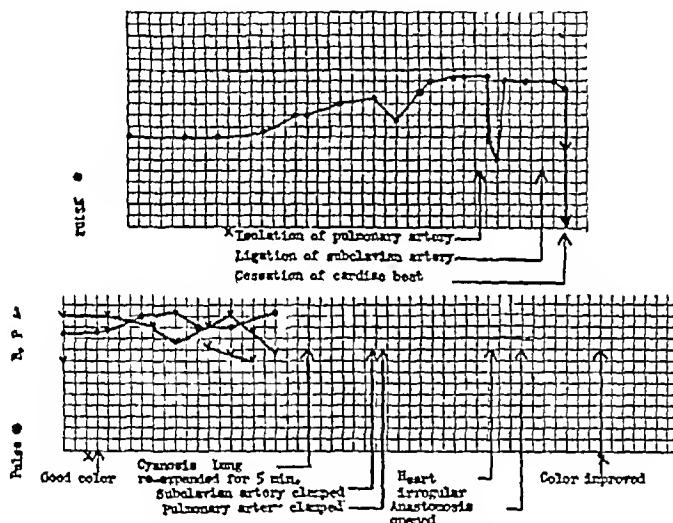


Fig 2.—The upper chart shows that the blood pressure was not obtainable at any time in an attempted anastomosis of the subclavian and pulmonary arteries (technic carbon dioxide absorption, endotracheal intubation). Cyclopropane and oxygen were used. The patient died on the operating table. The lower chart shows that the blood pressure was not obtainable before the vessels were clamped and the pulse was not obtainable. Anastomosis was completed, and the blood pressure later returned to normal, but the patient died six hours after operation. Anastomosis was of the subclavian and pulmonary arteries, and cyclopropane and oxygen were used (technic carbon dioxide absorption, endotracheal intubation).

the other hand, figure 2 shows the anesthesia charts in a fatal case. Blood pressure was not obtainable at any time. During the isolation of the pulmonary artery there was a decided fall in the pulse rate. Death occurred before the operation was completed. The lower chart shows serious fall in blood pressure before the anastomosis was begun. The operation was completed, and the blood pressure and pulse returned, but the patient did not survive. It is highly desirable, therefore, that sufficient circulation to the brain be maintained in these cyanotic

patients. Periods of rest for the patient, when the lung is reexpanded, helps a great deal to maintain an even blood pressure and pulse. It might even be wise to discontinue the procedure until another day if the circulation cannot be adequately maintained before the anastomosis is begun.

One patient in this group deserves special mention because of his mental state. A 4½ year old boy showed decided evidence of mental deficiency. He could not talk and could not be taught the simple acts of obedience in the home. He acted as though he had no cerebrum. After the operation and while he was convalescing the nurses began to notice that the child took interest in things about him. He pointed to the food he desired, and he began to play with toys. He is now in a kindergarten school, and his teacher informs me that, in her opinion, this child will be able to enter a regular school.

ADDENDUM—Since this paper was read, there has been sufficient time to observe the mental state of this patient. Although there was decided improvement following the operation, the mental status is now apparently not progressively improving.

Since the preparation of this paper, 11 additional patients have been operated on, with 1 fatality. This death was due, at least in part, to acute laryngotracheobronchitis.

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ANESTHETIC MORTALITY IN INTRATHORACIC SURGERY

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DURING the past thirteen years rapid advancement has been made in the surgical management of intrathoracic lesions. In 1933 Graham¹ performed the first successful removal of the entire lung for carcinoma of the bronchus. Adams and Phemister² made the first successful one stage resection of the lower part of the esophagus and esophagogastrostomy for carcinoma performed through the thorax in 1938. Gross³ in 1939 reported closure of a patent ductus. Crafoord and Nylin⁴ in 1944 were the first to relieve successfully the ill effects of coarctation of the aorta by resection and anastomosis. Blalock and Taussig⁵ in 1944 performed the first operation in human beings for the correction of pulmonary stenosis.

Intrathoracic surgery is accompanied with many unusual surgical and anesthetic hazards. The dangers of an open pneumothorax were understood by Andreas Vesalius,⁶ who in 1555 demonstrated to his students at Padua not only the untoward effects on the cardiorespiratory mechanism of open pneumothorax, with its alterations of intrathoracic pressures, but also a means of avoiding or overcoming them. For cen-

From the Department of Surgery of the University of Chicago

1 Graham, E A and Singer, J J Successful Removal of Entire Lung for Carcinoma of Bronchus, J A M A **101** 1371-1374 (Oct. 28) 1933

2 Adams, W E, and Phemister, D B Carcinoma of the Lower Thoracic Esophagus Report of a Successful Resection and Esophagogastrostomy, J Thoracic Surg **7** 621 (Aug.) 1938

3 Gross, R E., and Hubbard J P Surgical Ligation of a Patent Ductus Arteriosus, J A M A **112** 729-731 (Feb 25) 1939

4 Crafoord, C., and Nylin, G Congenital Coarctation of the Aorta and Its Surgical Treatment, J Thoracic Surg **14** 347-361 (Aug.) 1945

5 Blalock, A., and Taussig, H. B. The Surgical Treatment of Malformations of the Heart, J A M A **128** 189-202 (May 19) 1945

6 Vesalius, A De corporis humanae fabrica libre septum, cited by Bradshaw, H H Anesthesia for Intrathoracic Operations J Thoracic Surg **8** 293-299 (Feb.) 1939

turies the dangers of an open pneumothorax were remembered, but the means of obviating these dangers were not applied to problems in intrathoracic surgery.

The need for intrathoracic operations arises frequently in the management of neoplastic, inflammatory and congenital lesions of the organs

TABLE 1.—*Intrathoracic Operations Performed on Six Hundred and Eighty-Eight Patients*

Operation	Number
Pneumonectomy	48
Bilobectomy or partial pneumonectomy	87
Lobectomy	79
Miscellaneous exploratory thoracotomies (mostly for carcinoma)	44
Heart or great vessels	33
Mediastinum	87
Esophagus and cardia	149
Repair of diaphragm through the chest	14
Massive resection of the chest wall	15
Sympathectomy	109
Vagotomy	85
Extrapleural pneumonolysis and plombage	88
Total	688

TABLE 2.—*Sex Incidence in Six Hundred and Eighty-Eight Intrathoracic Operations*

Operation	Male (Percentage in Parentheses)	Female (Percentage in Parentheses)	Total
Pneumonectomy	41 (85.4)	7 (14.6)	48
Bilobectomy or partial pneumonectomy	20 (54.1)	17 (45.9)	37
Lobectomy	27 (34.0)	51 (65.4)	78
Miscellaneous exploratory thoracotomy (mostly for carcinoma)	35 (78.3)	10 (21.7)	45
Heart and greater vessels	18 (53.1)	15 (46.9)	33
Mediastinum	24 (64.9)	13 (35.1)	37
Esophagus and cardia	125 (83.9)	24 (16.1)	149
Repair of the diaphragm through the chest	8 (57.1)	6 (42.9)	14
Massive resection of the chest wall (some lung also)	9 (60)	6 (40)	15
Sympathectomy	51 (40.7)	58 (53.8)	109
Vagotomy	70 (82.4)	15 (17.0)	85
Extrapleural pneumonolysis and plombage	21 (55.3)	17 (44.7)	38
Totals	419 (68.16)	230 (31.84)	688

within the thorax. Primary carcinoma of the lung comprises approximately 8 per cent of all malignant tumors. In men over 20 years of age carcinoma of the esophagus is fourth in frequency of all malignant tumors. It is said to be surpassed in frequency only by carcinoma of the stomach, lung and rectum.⁷ Also, carcinoma of the cardiac end

7 Adams, W. E. Some Recent Accomplishments of Thoracic Surgery, *Arch. Surg.* 50:277-285 (June) 1945.

of the stomach is resected either transthoracically or, much less frequently, by thoracolaparotomy

Many of these patients are grave anesthetic and surgical risks. Because of the nature of the lesions, a large percentage of the patients

TABLE 3—*Age Incidence*

Operation	Years								
	0 to 9	10 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 to 89
Pneumonectomy		1	2	2	16	17	10		
Bilobectomy or partial pneumonectomy	2	6	12	8	4	2	2	1	
Lobectomy	6	13	32	10	7	7	4		
Miscellaneous exploratory thoracotomy (mostly for carcinoma)		1	1	2	11	23	5		
Heart and greater vessels	6	10	6	5	5		1		
Mediastinum	1	2	3	9	8	11	2	1	
Esophagus and cardia	1	2	3	5	24	45	55	10	5
Repair of the diaphragm through the chest	1		1	1	5	4		1	
Massive resection of the chest wall (some lung also)	2	2	1	1	8	4	1	1	.
Sympathectomy	8	14	86	89	12				
Vagotomy	4	4	20	22	30	6			
Extrapleural pneumonolysis and plombage	2	6	14	12	3	1			
Totals	19	51	85	113	156	188	87	14	5

TABLE 4—*Physical State*

Operation	Good	Fair	Poor	Serious	Emergency
					Serious
Pneumonectomy	2	15	20	11	.
Bilobectomy or partial pneumonectomy		15	16	5	1
Lobectomy	5	30	39	5	
Miscellaneous exploratory thoracotomy (mostly for carcinoma)	4	12	16	9	2
Heart and great vessels		4	16	18	.
Mediastinum	8	12	12	4	1
Esophagus and cardia	10	61	64	14	1
Repair of the diaphragm through the chest	3	6	3		1
Massive resection of the chest wall (some lung also)	2	9	3	1	
Sympathectomy		20	69	20	
Vagotomy	53	39	3		
Extrapleural pneumonolysis and plombage		16	10	10	2
Totals	87	230	271	92	8
Percentage	12.7	33.4	39.3	13.3	1.2

are dehydrated and undernourished, anemic, coughing and dyspneic and have other manifestations of serious alterations in their cardiorespiratory mechanisms. Because of the serious anesthetic and surgical risk, it seemed timely to investigate the outcome in intrathoracic operations.



Fig 3.—Lateral roentgenograms of different densities showing projection of tumor into the mediastinum and anteriorly



Fig 4.—Lateral view of tumor showing projection anterior and posterior to sternum and stumps of costal cartilages

Sutures of tantalum wire were used through the plate and the costal cartilages to add additional stability. Flaps of skin were replaced. The subcutaneous tissues were closed with interrupted silk ligatures and the skin closed in the same manner. Blood and air were aspirated through catheters in both pleural cavities. At the end of the operation the catheters were removed, giving airtight closure to the chest.

During the operation, whole blood and plasma were administered to maintain the level of blood pressure, and oxygen exchange was maintained by intermittent positive pressure.

Gross Observations.—The specimen (figs 4 and 5) consisted of a large irregular firm ovoid mass which was projecting above and below the body of the sternum.

The stumps of five costal cartilages projected from the lateral margin. The mass itself, projecting above the sternum, measured 10 by 11 by 13.5 cm in diameter. The



Fig 5.—Longitudinal section. Lower end of body of sternum is shown in the lower center and upper end in the upper right and left corners.

portion on the other side of the ribs measured 9 by 6.5 by 3.5 cm in diameter. Grossly, it was a firm multilobulated mass which contained numerous cystic gelatinous-like structures protruding from the lateral margin. Similar cartilage cysts were found in the substernal region. On section the tumor was grayish pink and somewhat gelatinous and there were areas of hemorrhage situated in the central portion. The tumor seemed to arise from the body of the sternum, which showed invasion and destruction.

Microscopic Observations.—The section is composed mostly of cartilage tissue with deep basophilic-staining stromas, and the nuclei are markedly pyknotic. These were located in the lacunae, which varied in size and shape. These portions of cartilage were arranged in irregular shapes, and there were intervening spaces in which

iat cells and red blood cells could be seen. In one section cartilage arising from osteoid tissue was seen. Numerous vascular channels appeared between the trabeculae of bone, and there was occasional evidence of bone formation. The adjacent tissue had the appearance of fibrous stroma, in which the nuclei were large and appeared to be undergoing marked proliferation.

Diagnosis.—The diagnosis was osteochondrosarcoma.

Postoperative Course.—The immediate postoperative course was uneventful except for transient pain in the chest, tachycardia and dyspnea. For the first ten days the tantalum plate buckled with each respiratory movement. Later the

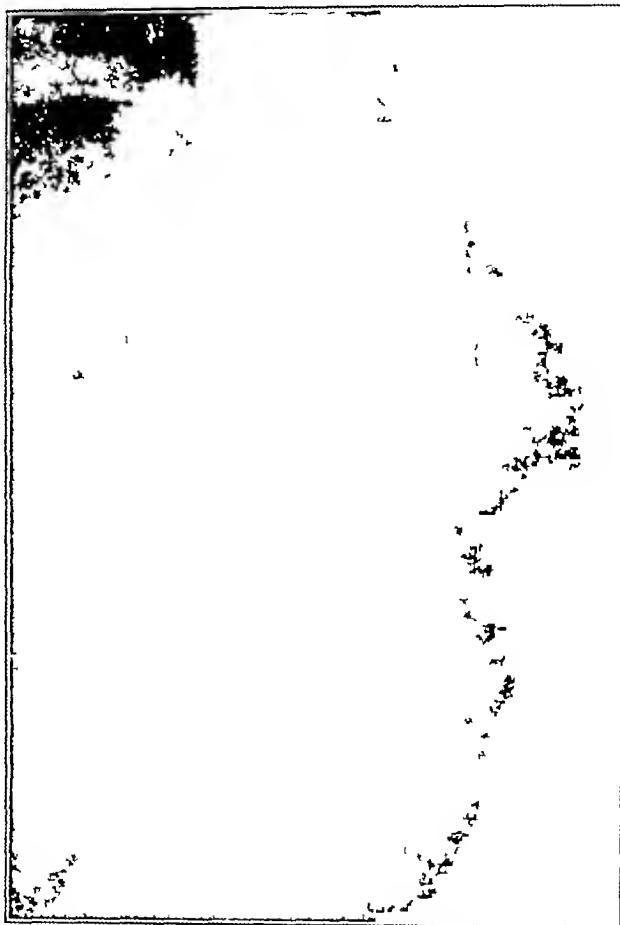


Fig. 6.—Roentgenogram made six weeks postoperatively showing tantalum plate in position.

thickening of surrounding tissues stabilized the plate so that buckling could neither be heard nor felt. Roentgenograms made on the seventh postoperative day showed a considerable amount of fluid in both pleural spaces. Several thoracenteses were done for accumulation of sterile fluid in the pleura. On the tenth postoperative day a small amount of serosanguineous drainage occurred from the vertical limb of the incision. Fifteen days postoperatively, tenderness of the left calf, with edema, developed. The following day the left femoral vein was ligated under local anesthesia. The edema and tenderness in the leg improved.

Thoracenteses were continued at infrequent intervals until September 19. Roentgenograms of the chest on this date and on October 11 showed no further effusion and only a slight amount of pleural thickening (fig 6). The incision continued to drain serosanguineous fluid, and on September 29 several large clots were evacuated through an opening in the inferior angle of the incision. The patient continued to improve, although slight drainage persisted (fig 7). Several courses of penicillin were given to prevent and control infection. However, clots and blood continued to accumulate about the plate, apparently because of the motion of the thoracic wall. For this reason the plate was removed on November 13.

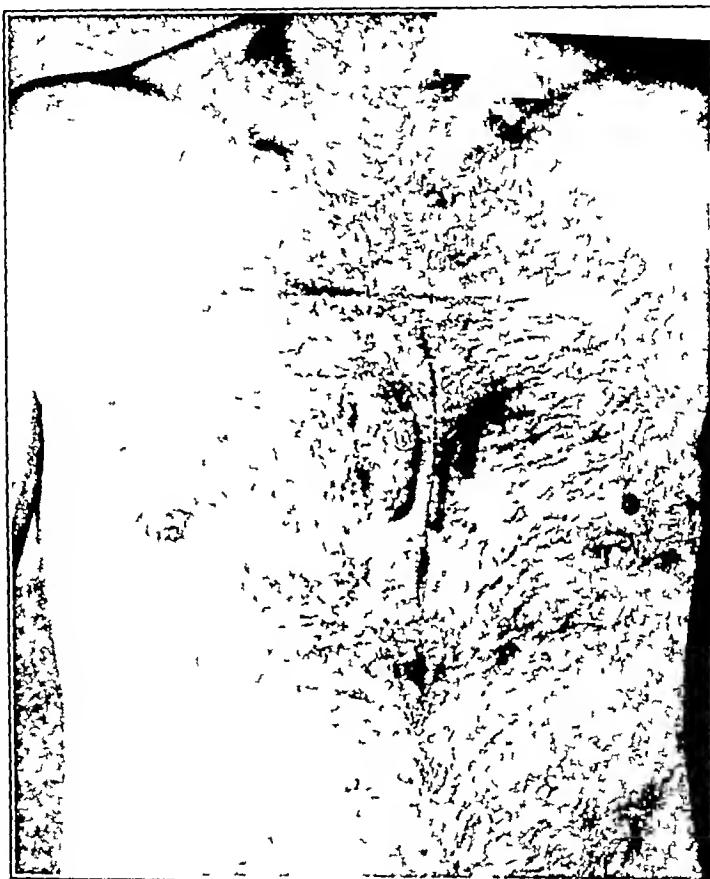


Fig 7.—Postoperative view showing small sinuses which drained clot and old blood until the plate was removed.

After removal of the plate there was no evidence of paradoxical respiration and the soft tissue of the anterior thoracic wall had become thickened and toughened. Drainage ceased, and the wound healed.

COMMENT

The large tantalum plate used in this patient was completely effective in preventing paradoxical respiration and maintaining good respiratory exchange during the postoperative period. The plate buckled with

each respiration during the early postoperative period. A plate 0.020 inch in thickness would have been preferable. It did not serve as a permanent prosthesis because of continuous bleeding around it caused by the trauma from respiratory movements. The plate could have been removed as early as three weeks postoperatively, at which time there was sufficient stabilization of the anterior thoracic wall and mediastinum to permit normal respiratory exchange.

SUMMARY

A case is reported in which a large portion of the anterior thoracic cage was removed because of osteochondrosarcoma of the sternum. A large tantalum plate was fitted into the defect. This plate functioned satisfactorily as a temporary prosthesis.

HERNIAL REPAIR USING COOPER'S LIGAMENT

Follow-Up Studies on Three Hundred and Sixty-Seven Operations

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DETROIT

DURING the past seven years we have studied a method of herniorrhaphy which utilizes Cooper's ligament in situations in which one would customarily use Poupart's ligament. This method was first advocated by Lotheissen¹ for use in femoral hernia and was extended to direct and some indirect hernias on the basis of the anatomic studies of McVay and Anson² (1940).

The conventional operations for the repair of hernia in the groin generally involve two principles. 1 Indirect inguinal, direct inguinal and femoral hernias are repaired by different methods. 2 When an inguinal approach is used, some structure is sutured to Poupart's ligament. The present method disregards both of these tenets and consists, in brief, of two essential features. 1 Those structures usually sutured to Poupart's ligament are fastened instead to Cooper's ligament (the ligamentum pubicum superius B N A). 2 Essentially the same technic can be used for all hernias of the groin, whether they are indirect or direct, inguinal or femoral, simple, sliding, incarcerated or strangulated.

The present study includes three hundred and sixty-seven hernias in the groin treated by the technic which utilizes Cooper's ligament during the seven year period subsequent to April 1940.

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb 22, 1947

From the Department of Surgery, Johns Hopkins University and the Johns Hopkins Hospital, Baltimore, and the Division of General Surgery, Henry Ford Hospital, Detroit.

1 Lotheissen, G Zur Radikaloperation de Schenkelhernien, Centralbl f Chir 25 548-550, 1898

2 Anson, B J, and McVay, C B Inguinal Hernia I The Anatomy of the Region, Surg, Gynec & Obst 66 186-191 (Feb 1) 1938, Aponeurotic and Fascial Continuities in the Abdomen, Pelvis and Thigh, Anat. Rec. 76 213-231 (Feb 24) 1940, Composition of the Rectus Sheath, ibid. 77 213-225 (June 25) 1940

HISTORICAL DATA

The principle of suturing the transversalis fascia and the attached structures to Cooper's ligament is not new. Apparently Narath³ was the first to use this technic, but especial credit should go to Lotheissen (1898), who made the first written report. Lotheissen used the technic in 12 cases of femoral hernia, with no recurrences, the longest period of observation being one year. His method involved an exposure of Cooper's ligament by slight lateral retraction of the femoral vessels. He then sutured the muscular edge of the internal oblique to Cooper's ligament with four to five heavy silk stitches. Lotheissen refers to this step of the procedure as follows: "Then comes the most difficult act, the drawing out through the ligament of Cooper."

Other writers on the subject were Fischer,⁴ Groves,⁵ Stetten,⁶ Andrews,⁷ Keynes,⁸ Dickson,⁹ McVay,¹⁰ Goinard,¹¹ McClure and Fallis,¹² Amendola,¹³ Neuhof,¹⁴ McVay and Anson,¹⁵ Harkins, Szilagyi, Brush and Williams,¹⁶ Harkins and Swenson,¹⁷ Hyde,¹⁸ Sauer,¹⁹ Clark

³ Narath (1898) cited by Lotheissen¹

⁴ Fischer, H Lotheissen's Operation for Femoral Hernia, Ann Surg **69** 412-434 (April) 1919

⁵ Groves, E W A Note on the Operation for the Radical Cure of Femoral Hernia Brit J Surg **10** 529-531 (April) 1923

⁶ Stetten, DeW Further Observations on a Modified Inguinal Hernioplasty Technic with Completed Utilization of the Aponeurosis of the External Oblique, Ann Surg **78** 48-60 (July) 1923

⁷ Andrews, E The Closure of Large Femoral and Inguinofemoral Defects The Result of Destruction or Relaxation of Poupart's Ligament, Surg, Gynec & Obst **39** 754-759 (Dec.) 1924

⁸ Keynes, G The Modern Treatment of Hernia, Brit M J **1** 173-179 (Jan 29) 1927

⁹ Dickson, A R Femoral Hernia, Surg, Gynec. & Obst. **63** 665-669 (Nov) 1928

¹⁰ McVay, C B An Anatomic Error in Current Methods of Inguinal Herniorrhaphy Ann Surg **113** 1111-1112 (June) 1941

¹¹ Goinard P Cure radicale de certaines hernies inguinales par fixation du tendon conjoint au ligament de Cooper, Presse med **47** 872 (May 31) 1939

¹² McClure, R D, and Fallis, L S Femoral Hernia Report of Ninety Operations Ann Surg **109** 987-1000 (June) 1939

¹³ Amendola, H Repair of Hernia with a Silk Binding Stitch, read before the New York Surgical Society, Oct. 8, 1941

¹⁴ Neuhof, H An Operation for Inguinal Hernia Based upon the Utilization of Cooper's Ligament, Surgery **12** 128-132 (July) 1942

¹⁵ McVay, C B, and Anson, B J Fundamental Error in Current Methods of Inguinal Herniorrhaphy, Surg, Gynec. & Obst. **74** 746-750 (March) 1942

¹⁶ Harkins, H N, Szilagyi, D E, Brush, B E, and Williams, R Clinical Experiences with the McVay Herniotomy One Hundred and Thirty-One Personal Cases Surgery **12** 364-377 (Sept.) 1942

and Hashimoto,²⁰ McLaughlin and Brown,²¹ Mattson,²² Blodgett,²³ Burton²⁴ and Garner²⁵

The article by McVay and Anson¹⁶ summarizes the coordinated views of these men concerning the true nature of inguinal hernia and the proper repair of the condition. They stated

In the more common types of inguinal herniorrhaphy the transversalis fascia and, variously, the transversus abdominis and internal oblique layers are sutured to the inguinal ligament, providing a poor substitute for their normal insertion. The inguinal ligament is not the insertion of the transversalis fascia, the transversus abdominis aponeurosis, or the internal oblique aponeurosis, its relationship to these structures is simply one of contiguity. From an anatomical standpoint this is reason enough for endeavoring to find some other structure for anchorage. Moreover, from a surgical point of view, the inguinal ligament does not make a suitable substitute for their regular insertion because of its character. In the repair of large indirect and direct inguinal hernias, it is recommended that the inguinal layers be sutured to Cooper's ligament and not to the inguinal ligament. It is pointed out that the inguinal ligament is neither the normal insertion of the inguinal strata nor a suitable substitute for such attachment, on the contrary, the superior pubic ligament, Cooper's ligament, which is the normal insertion, is readily accessible, intrinsically strong, and directly fixed to bone.

The anatomic studies of McVay done under the direction of Anson in the Department of Anatomy of Northwestern University and later

17 Harkins, H N, and Swenson, S A, Jr. A Cooper's Ligament Herniotomy Clinical Experience in Three Hundred and Twenty-Two Consecutive Cases, *S Clin North America* **23** 1279-1297 (Oct) 1943 Swenson, S A, Jr., and Harkins, H N. The Surgical Treatment of Recurrent Inguinal Hernia with Special Reference to a Cooper's Ligament Herniotomy and the Use of Free Fascia Grafts, *Surgery* **14** 807-818 (Dec) 1943 Harkins, H N. The Surgical Treatment of Hernia, *New Orleans M & S J* **99** 47-49 (Aug) 1946

18 Hyde, T L. Inguinal Herniorrhaphy, *Am J Surg* **69** 182-189 (Aug) 1945

19 Sauer, I. Hernia inguinal Leus dismorfismos e maneira de corrigi-los (técnica de Lotheissen-McVay), *Rev méd muníc* **6** 419-433 (May-June) 1945

20 Clark, J H, and Hashimoto, E I. Utilization of Henle's Ligament, Iliopubic Tract, Aponeurosis Transversus Abdominis and Cooper's Ligament in Inguinal Herniorrhaphy. A Report of One Hundred and Sixty-Two Consecutive Cases, *Surg, Gynec. & Obst* **82** 480-484 (April) 1946

21 McLaughlin, C W, Jr., and Brown, J R. Inguinal Hernias and Allied Defects in Naval Recruits. An Analysis of 1,406 Patients Admitted to Surgical Treatment, *Surgery* **19** 267-274 (Feb) 1946

22 Mattson, H. Use of Rectus Sheath and Superior Pubic Ligament in Direct and Recurrent Inguinal Hernia, *Surgery* **19** 498-503 (April) 1946

23 Blodgett, J B. A Study of the Effects of Early Rising in the Post-operative Period, read at the meeting of the Society of University Surgeons, Boston, Feb 13, 1947

24 Burton, C C. Rationale and Factors for Consideration in Cooper's Ligament Hernoplasty, *Internat Abstr Surg* **85** 1-8 (July) 1947

25 Garner, A D. Inguinal Hernia. An Analysis of 2,643 Operations, *Am J Surg* **74** 14-23 (July) 1947

applied to the surgical repair of hernia by McVay are succinctly expressed in the previous paragraph. After hearing a lecture by McVay in April 1940 one of us (H N H) began the present study. After applying McVay's principles to the surgical repair of three hundred and sixty-seven hernias of the groin we have little to find at variance with his opinions.

COOPER'S LIGAMENT (LIGAMENTUM PUBICUM SUPERIUS)

The relationships between Cooper's ligament and the pubis below and Poupart's (inguinal) ligament above are clearly shown in figures 1

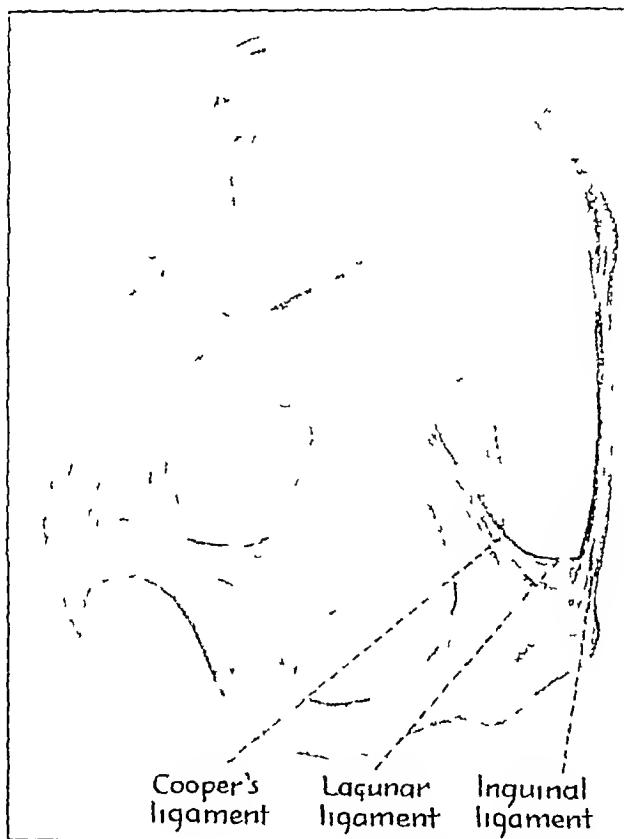


Fig 1.—Cooper's ligament. View of the left half of the pelvis with attached ligaments. The relationships between the firmly anchored Cooper's ligament and the loose inguinal ligament are clearly shown.

and 2. Cooper's ligament has received relatively little attention in the literature. Seelig and Tuholske²⁶ stated "It is equally unfortunate

²⁶ Seelig, M. G., and Tuholske, L. The Inguinal Route Operation for Femoral Hernia, with a Supplementary Note on Cooper's Ligament, Surg., Gynec & Obst. **18** 55-62 (Jan.) 1914.

that probably the most important structure utilized in the closure of the femoral ring, namely, Cooper's ligament, is not only not pictured in any of the anatomies but also is not adequately described in most of them." Cooper's ligament was first described by Sir Astley Cooper²⁷ when he pictured the os pubis as being "covered by a ligamentous expansion, which forms a remarkably strong production above the linea iliopectinea, extending from the tuberosity of the pubis outward and projecting from the bone over that line."

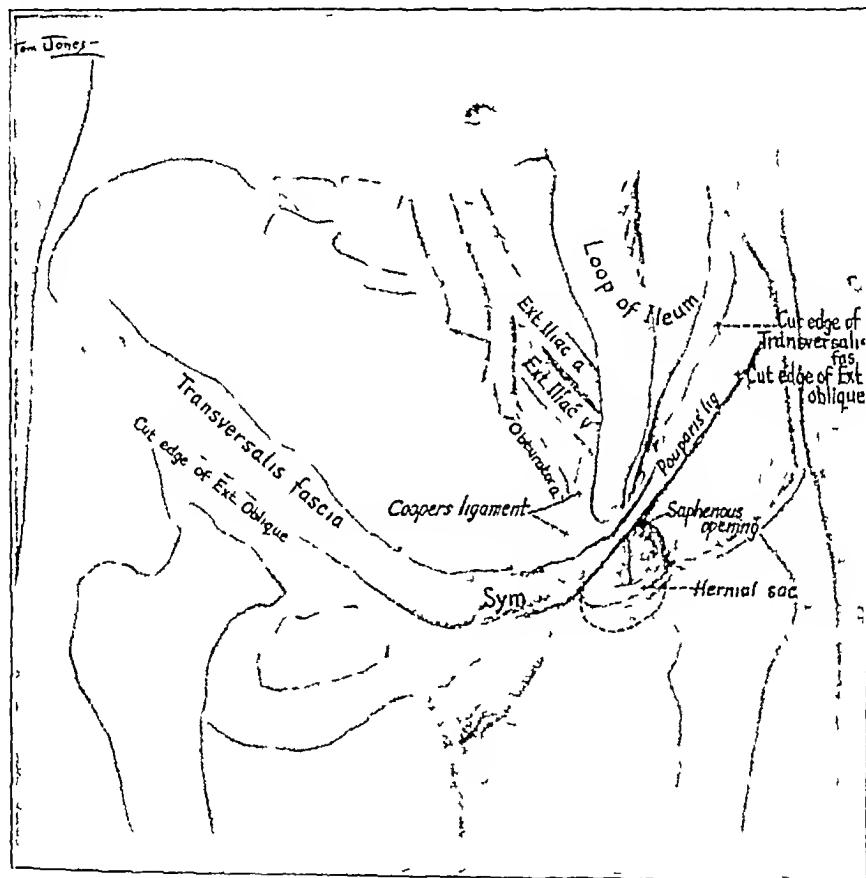


Fig 2.—The relationship between femoral hernia and Cooper's ligament (From Seelig and Tuholske *Surg, Gynec & Obst* 18:57, 1914)

SELECTION OF CASES

In the period between April 24, 1940, and June 30, 1943, three hundred and twenty-two operations utilizing Cooper's ligament were done at the Henry Ford Hospital. In the period from July 1, 1943, to Jan 12, 1947, forty-five such operations were done at the Johns Hopkins Hospital.

²⁷ Cooper, A (1804), cited by Seelig and Tuholske²⁸

During the period from April 24, 1940, to Aug. 31, 1941, the procedure was used by one of us (H N H) in the treatment of only large indirect, direct or femoral hernias. During the entire period of study the procedure was applied by the assistants only in the more difficult cases. Thus any selection of material was to the distinct disadvantage of the technic utilizing Cooper's ligament, the simpler hernias being treated by the better known Bassini method or by the original Halsted method.

From Sept. 1, 1941 until the close of the study on Jan. 12, 1947 (a period of over five years) one of us (H N H) used the Cooper ligament technic in all cases except 1, in this instance a simple congenital hernia in a young man with strong fascial structures was operated on in October 1946 by the modified Halsted method without transposition of the cord.

TECHNIC

GENERAL PRINCIPLES—The general principles of Cooper's ligament technic of repair of hernia as applied by us include the following:

1. Silk sutures were used throughout in all cases. In no instance in the series at the Henry Ford Hospital was a single silk suture extruded from the wound. In the 45 cases in the series at the Johns Hopkins Hospital infected silk had to be removed from the hernial wounds in 2. Except for purse-string sutures, all stitches were of the interrupted type.

2. Spinal anesthesia was employed in most cases. It is felt that the greater relaxation given by this type of anesthesia outweighs its disadvantages. Occasionally supplementary anesthesia with nitro-gen and ether was employed, in older patients or in others in whom the risk was poor, local anesthesia was preferred.

3. Skin towels fastened to the edges of the wound were used in all patients. In the series at the Henry Ford Hospital shaving of the skin and preliminary sterile preparations were done the evening before, followed by the application of a 3.5 per cent solution of iodine at the time of operation. In the group of patients at the Johns Hopkins Hospital the shaving and the other preparations were done at the time of operation.

4. Rest in bed for twelve days was advocated at the Henry Ford Hospital in cases of simple unilateral hernia, with discharge from the hospital on the fourteenth day. Patients with bilateral hernia were kept in bed for fifteen days and those with recurrent hernia for nineteen days. Return to full manual labor was permitted in five weeks for patients with simple hernia and in six weeks for the patients with bilateral or recurrent hernia. During the past two years, almost all patients have been encouraged to get out of bed in less than twenty-four hours after operation.

5 The time required for the operation is no greater than that for the more conventional procedures. The only special equipment needed is a round small curved Mayo needle (no 6 or 7) and a good needle holder. A Bland or a Jones needle holder is desirable but not absolutely essential.

STEPS.—The repair of hernia in the groin which utilizes Cooper's ligament can be divided into ten steps. A step by step outline of the procedure follows.

1 *Exposure of the Cord and Opening of the Indirect Sac*.—The incision in the skin is made from 1 cm medial to the anterosuperior

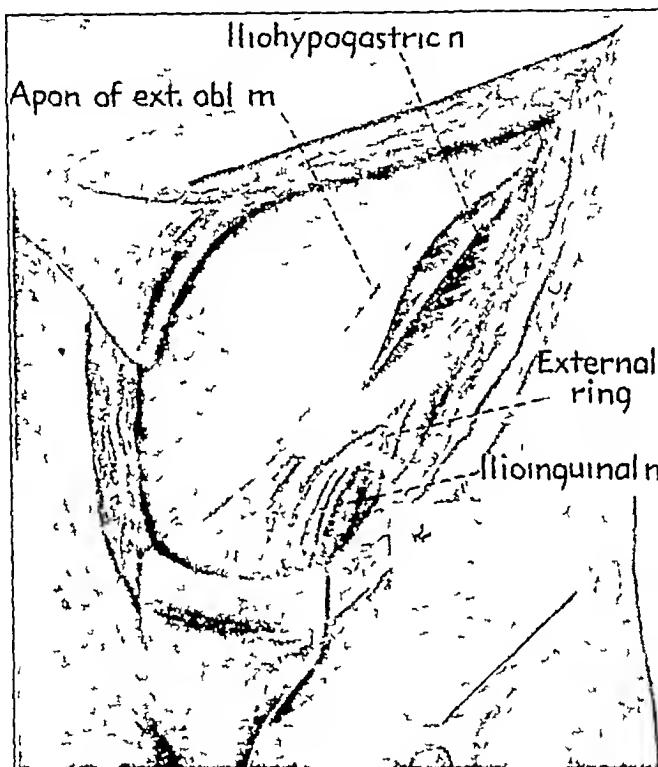


Fig. 3.—Cooper's ligament herniorrhaphy—incision of the skin and beginning of incision of the external oblique aponeurosis. The external oblique aponeurosis is usually opened in the direction of its fibers so that the opening will be even with the upper border of the external ring. The underlying iliohypogastric nerve is carefully avoided. (From *S Clin North America*, October 1943.)

iliac spine to over the pubic spine, which exposes the external oblique aponeurosis. The external ring is exposed and the external oblique aponeurosis split in the direction of its fibers even with the upper border of the ring to allow for an adequate lower flap. This splitting with the scalpel is best begun 3 cm from the ring, as shown in figure 3, to avoid the nerves where they are adherent to the ring. The split is then extended laterally and upward with scissors and then more carefully downward in the direction of the external ring after the iliohypogastric

nerve which is often adherent to the under surface of the external oblique aponeurosis at this level, has been carefully peeled away. When cutting occurs accidentally, it is usually near the external ring, and it may be prevented by approaching the latter from the lateral side. The cord and the surrounding structures are then separated from the lower leaf of the external oblique aponeurosis and Poupart's ligament and then from the region of the pubic spine and conjoined tendon so that finally the cord is freed entirely except at both ends. The indirect sac, which is always present even in normal persons, is located upward and medially from the internal ring.

In all cases, whether the hernia is indirect inguinal or femoral, the indirect sac is opened. In many cases of direct inguinal hernia or femoral hernia the indirect sac will be normal in size, but it can always be found above and medial to the cord. In cases of complete indirect inguinal hernia of the congenital type or in cases in which the hernial sac is long the latter is cut across near the internal ring and separated from the cord. The proximal end is closed by an internal purse-string suture, as outlined later, while the distal end is left in place. Many surgeons are of the belief that to leave the distal sac in place will cause hydrocele. This has not been our experience, and we believe that the hematomas that result from the removal of the distal sac are far more disastrous than any theoretic occurrence of hydrocele.

2. Exploration of Hesselbach's Triangle and of the Femoral Ring.— Once the indirect sac is opened, it is a simple matter to insert the gloved finger and feel Hesselbach's triangle for a direct weakness or obvious direct hernia and to feel the femoral ring. It is indeed surprising how few surgeons will take the extra thirty seconds to perform this exploration, and many femoral and direct hernias that "recur" are overlooked because this maneuver was not performed. Exploration with the finger tip as shown in figure 4 of the femoral ring and Hesselbach's triangle should be an essential feature of all hernial repairs.

3. Hoguet's Maneuver—Transposition of Direct or Femoral Sacs Into the Indirect Sac.— If a direct sac is present as shown in figure 5, it should be transposed laterally to the inferior epigastric vessels by the technic of Hoguet²⁸ (1920), which has since been popularized by Fallis²⁹. Thus the direct and indirect sacs are converted into one. This step may be described in Hoguet's own words as follows: "By traction outward on the indirect sac, all of the peritoneum of the direct sac may be pulled external to the vessels and the two sacs converted into one. An indirect sac can always be found in these cases, although it may be very

²⁸ Hoguet, J. P. Direct Inguinal Hernia, Ann Surg 72: 671-674 (Dec) 1920.

²⁹ Fallis, L. S. Inguinal Hernia. A Report of 1,600 Operations, Ann Surg 104: 403-418 (Sept) 1936; Direct Inguinal Hernia, ibid 107: 572-581 (April) 1938.

small." The same procedure may be used to convert a femoral sac into an indirect sac, as practiced by McClure and Fallis.¹² This maneuver is extremely useful. In general, no matter how large a direct sac is it is not opened but is merely transposed. In the case of large direct sacs the transversalis fascia can be infolded with numerous interrupted silk sutures. One advantage of not opening a direct sac is that the danger of opening the bladder is largely obviated. In some instances all three sacs can be converted into a single indirect sac, which in turn can always be dealt with as described in step 4.

4 Internal Purse-String Closure of Indirect Sac—The indirect sac, whether it is simple or enlarged by the added conversion of direct and

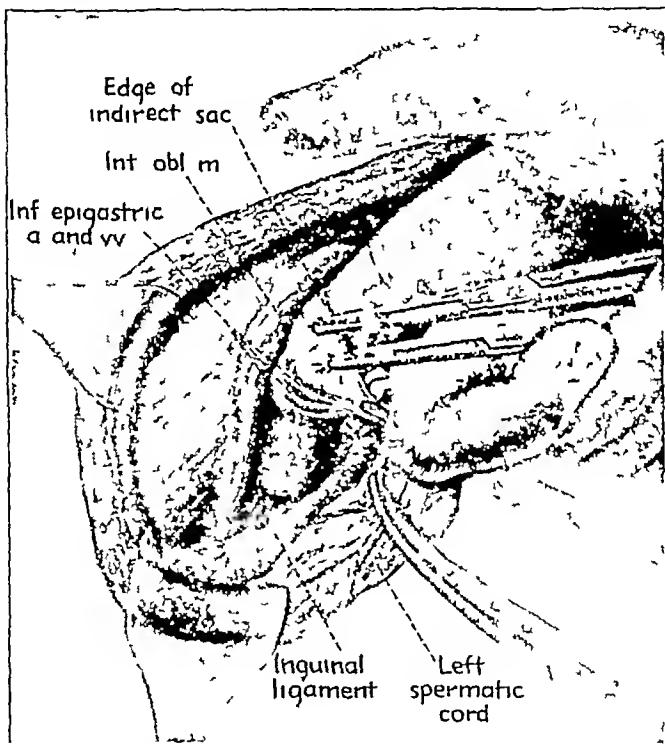


Fig 4—Cooper's ligament herniorrhaphy—exploration through the opened indirect sac. The latter is always opened and any femoral or direct sac is transposed by the method of Hoguet to become part of the indirect sac. The tip of the examining finger is in a small direct sac (From *S Clin North America*, October 1943).

femoral sacs, is then closed with an internal purse-string suture of medium or heavy silk, as shown in figure 6. Many stitches are taken with a round noncutting needle so as to include all crevices. Such a closure is done as high as possible to prevent indirect recurrences.

5 Plastic on the Internal Ring—MacGregor's Maneuver—When the free ends of the purse string are cut and the peritoneum snaps back, the defect in the transversalis fascia at the internal ring is seen to be

large and in many instances will admit even three or four fingers. The fascia is grasped with Allis clamps at numerous points around the internal ring above and medially as far as the inferior epigastric vessels—but not inferior to the cord—and a second partial or semilunar purse-string suture of medium or heavy silk is made in the transversalis fascia. This ensures a snug fit around the cord, but the purse string itself does not surround the cord. Essentially this step involves the suturing of the transversalis fascia, Henle's ligament and cremaster muscles together. Occasionally the conjoined tendon may be included in the sutures, but the shelving edge of Poupart's ligament should not be

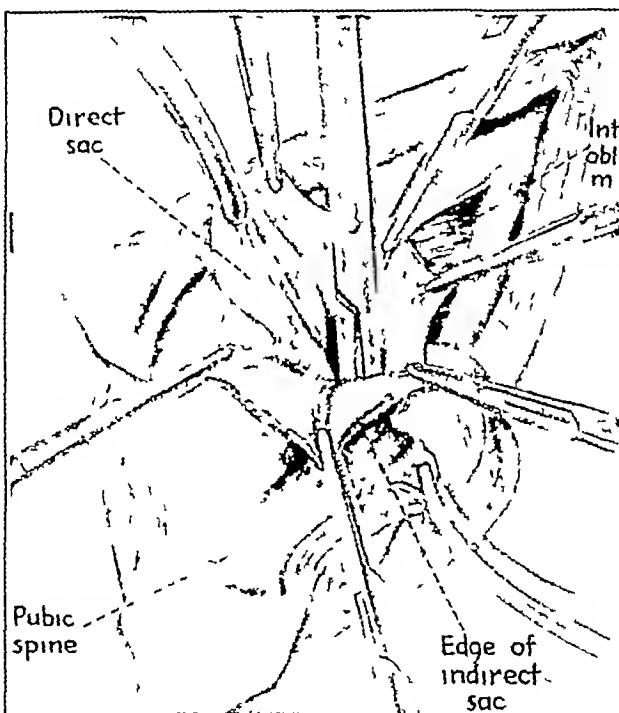


Fig 5—Cooper's ligament herniorrhaphy—Hoguet's maneuver. The direct sac has now been transposed and the gauze-tipped Kuttner dissector is holding back the intestines (From *S Clin North America*, October 1943.)

included since the normal and desirable retractile sphincter-like action of the internal ring demonstrated by MacGregor³⁰ would be interfered with. The use of Henle's ligament has been especially described by Clark and Hashimoto²⁰

³⁰ MacGregor, W. W. The Demonstration of a True Internal Inguinal Sphincter and Its Etiologic Role in Hernia, *Surg, Gynec & Obst.* **49** 510-515 (Oct.) 1929, The Fundamental Operative Treatment of Inguinal Hernia, *ibid* **50** 438-440 (Feb.) 1930, Observations on the Surgical Treatment of Hernia, *Ann Surg* **122** 878-884 (Nov.) 1945

6 Relaxation of the Internal Oblique Muscle—The inner layer of the anterior rectus fascia is usually split for a distance of about 3 inches (7.6 cm) from a point 2 cm above the pubic spine upward and laterally. This is done almost exactly as described by Rienhoff³¹ and as shown in figure 7. The external oblique is lifted up by the assistant and the internal oblique cut just lateral to the junction of the two to where they form the linea alba. The rectus and pyramidalis muscles are exposed. The iliohypogastric nerve and the adjoining nerves and vessels which enter the rectus muscle through the internal oblique aponeurosis at this point can be avoided easily. This relaxation allows the internal oblique

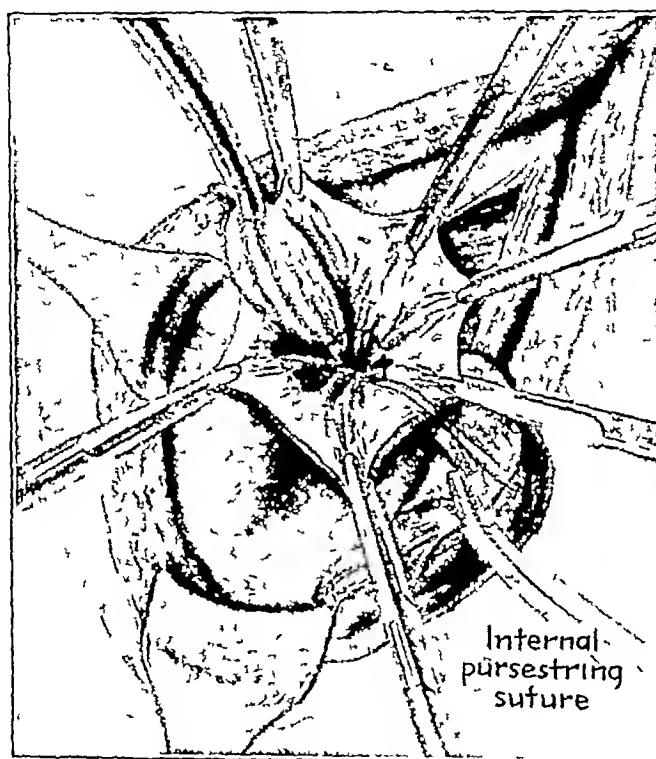


Fig 6.—Cooper's ligament herniorrhaphy—internal purse-string suture. This suture completely closes the sac and by small bites obliterates all its folds. The redundant sac (proximal to its division and distal to the purse-string suture) is usually placed inside the internal ring but, if large, may be excised. (From *S Clin North America*, October 1943.)

and the attached transversalis fascia to be pulled down for the subsequent repair without tension.

7 Sutures Into Cooper's Ligament—The “red” muscle of the internal oblique is entirely disregarded and even may be excised for convenience where it overlies the “conjoined tendon.” Usually it is

³¹ Rienhoff, W. F., Jr. The Use of the Rectus Fascia for Closure of the Lower or Critical Angle of the Wound in the Repair of Inguinal Hernia, *Surgery* 8: 326-339 (Aug.) 1940.

elevated with a small retractor and the "conjoined tendon" located with a gauze (Kuttner) dissector. If the transversalis fascia appears strong enough, it alone is used for the upper leaf of the repair. If it is not adequate, one must go higher and include the internal oblique aponeurosis. In no instance, however, should "red" muscle be used. The transversalis fascia, and often the "conjoined tendon" therefore, forms the upper leaf of the repair, while Cooper's ligament is the lower leaf. As stated previously, Cooper's ligament is an extremely tough thickening of the periosteal structures on the anterosuperior surface of the anterior ramus of the pubis.

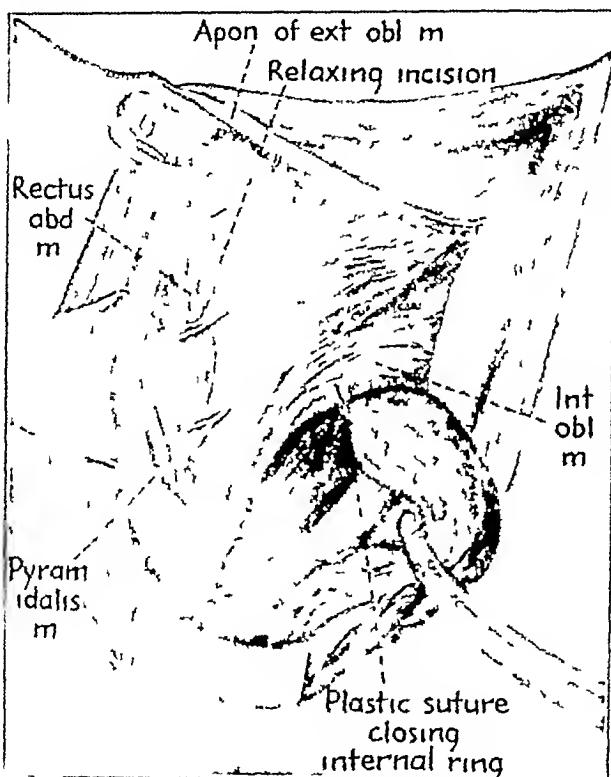


Fig. 7.—Cooper's ligament herniorrhaphy—plastic closure of internal ring and relaxation of internal oblique muscle. The internal ring has been closed by a plastic stitch in the transversalis fascia while the internal oblique has been relaxed close to its junction with the external oblique aponeurosis to form the linea alba. An attempt is made to spare the nerves and accompanying blood vessels. (From *S Clin North America*, October 1943.)

During the first year or so that this repair was used, Cooper's ligament was visualized by breaking down Hesselbach's triangle. Then for a year or so the sutures were applied blindly, Hesselbach's triangle being left intact. Recently however, there has been a return to the principle of direct visualization of Cooper's ligament, it being decided that it is easier and safer to apply the sutures when there is direct vision.

McVay³² uses the method of direct visualization. After separation of the fascia over the anterior ramus, Cooper's ligament is exposed. The left index finger is placed on the anterior ramus of the pubis near the spine and moved laterally along the crest until the femoral vessels are reached. This is usually about 4 cm lateral to the spine of the pubis. Since the finger is held in close contact with the bone, the vessels being kept lateral, and the first stitch is placed medial to the finger there is little danger of damaging the vessels. The first stitch is thus usually 3 to 4 cm lateral to the pubic spine. Therefore, since the upper leaf is to be grabbed with the suture first, the needle goes through the trans-

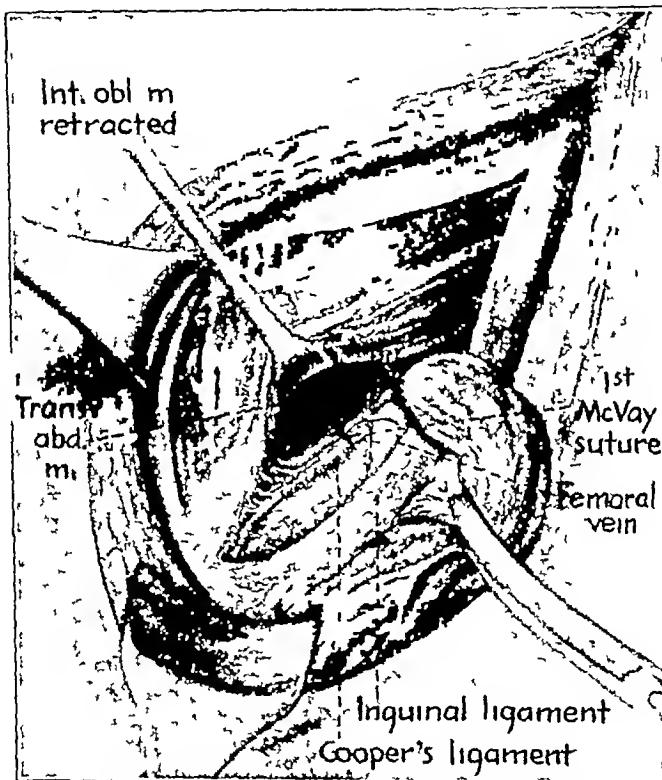


Fig 8.—Cooper's ligament herniorrhaphy—first Cooper's ligament suture. This suture joins the transversalis fascia and adjoining "conjoined tendon" above to Cooper's ligament below. The most lateral suture is placed first and is separated from the femoral vessels, which lie laterally, by the tip of the left index finger of the operator, the finger being held tightly in contact with the pubic bone underlying Cooper's ligament.

versalis fascia a corresponding distance of about 4 cm from the pubic spine and then through the thick Cooper ligament on the upper border of the pubic ramus. The stitch is then tied as shown in figure 8 and the intervening gap between this point and the pubic spine is closed with three or four similar sutures, as shown in figure 9. The most medial sutures usually go through Gimbernat's (lacunar) ligament as

³² McVay. Personal communication to the authors, Feb 21, 1947.

well as Cooper's. It is important that the most lateral suture be placed first, as otherwise it is more difficult to protect the vein. The sutures into Cooper's ligament are of double heavy silk and are applied with a small round curved Mayo needle, which is best held with a Bland or a Jones needle holder. The double strands are made into a triple knot, and then the individual strands are separated and tied in pairs (this is called "braiding"). The relatively large amount of silk used has seldom caused trouble. In certain cases, because of the prominence of Rosenmüller's gland (a lymph gland lying over Cooper's ligament about 2 cm medial to the femoral vessels) or because of doubt as to the position

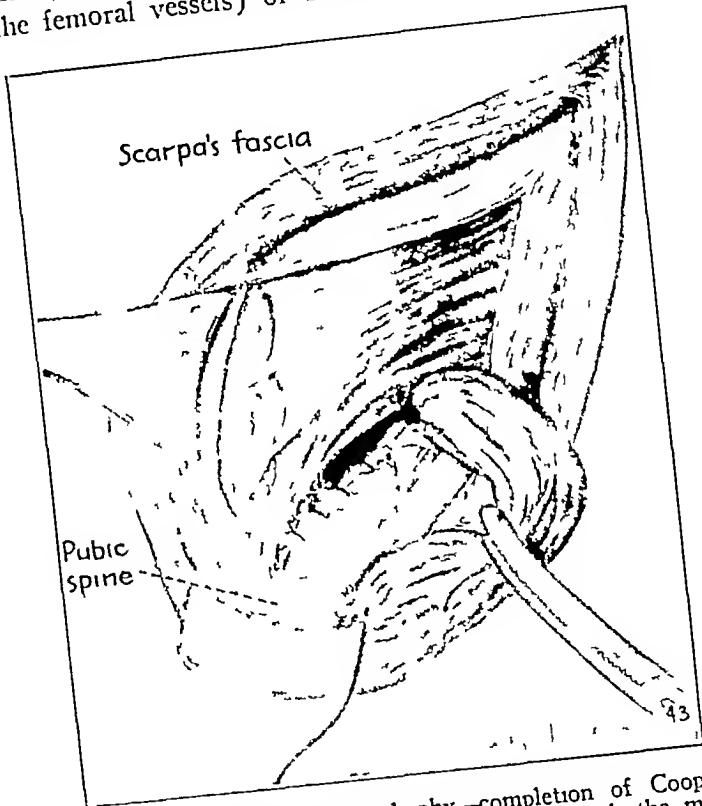


Fig. 9—Cooper's ligament herniorrhaphy—completion of Cooper's ligament sutures. Usually four or five such sutures are introduced, the most medial of which also pass through the lacunar (Gimbernat's) ligament (modified by H. W. Symmes, original drawing by Evelyn Erickson).

of the vein the sutures are carried out only half way or more from the pubic spine to the femoral vessels. This is termed a partial operation or a "partial McVay," and in the 230 most recent cases it has only been done twice (0.9 per cent). Babcock³³ advised one such medial

³³ Babcock, W. W. The Ideal in Herniorrhaphy. A New Method Efficient for Direct and Indirect Inguinal Hernia, Surg., Gynec. & Obst. 45: 534-540 (Oct) 1927.

suture in conjunction with his operation for direct hernia. The space between the most lateral stitch in Cooper's ligament and the plastic suture on the internal ring often seems to be a possible weak spot to those doing the operations for the first time. Actually this is not so, because the arched internal oblique muscle will tend to close this defect on contraction. Any attempt to tighten it by suturing the internal oblique or "conjoined tendon" to Poupart's ligament defeats the purpose of the operation. Such a step interferes with the sphincter-like action of the internal ring and tends to pull the transversalis fascia away from Cooper's ligament.

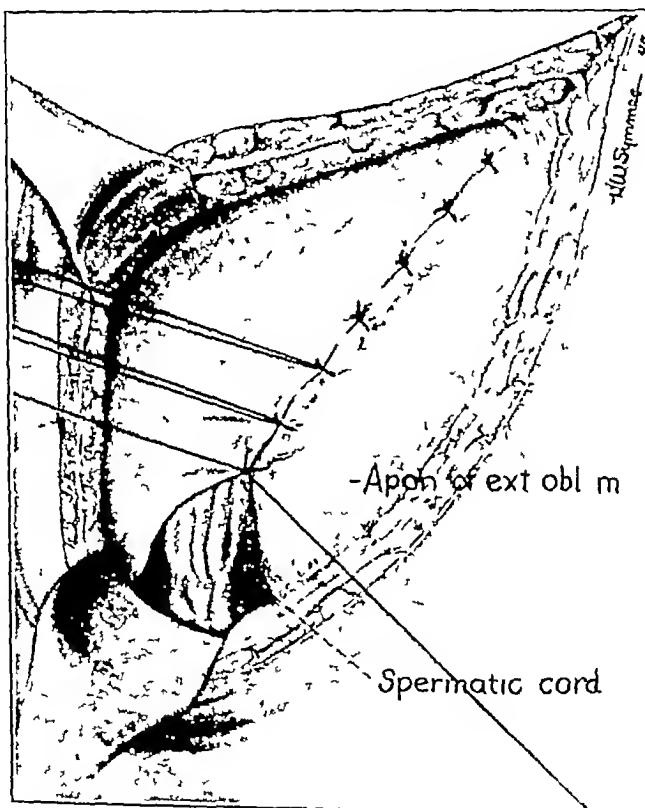


Fig. 10.—Cooper's ligament herniorrhaphy—superficial closure. The cord is dropped into the dead space and the external oblique aponeurosis (as in the figure), Scarpa's fascia and the skin are closed with interrupted silk sutures in layers over the cord.

8 Closure of the External Oblique Aponeurosis—In the first third of this series of cases the external oblique aponeurosis was closed beneath the cord after the manner of the original Halsted-I procedure in the majority (61 per cent). In the more recent two thirds of the series, however, it has most often been closed over the cord, the latter being dropped into the dead space left by the closure. Thus more recently the usual closure of the external oblique has been done in a typical

Bassini manner (97 per cent) We call these two variations of the procedure the Halsted-I-Lotheissen and the Bassini-Lotheissen There has been one recurrence when the former method was used and two when the latter was used In both procedures the external oblique is closed with interrupted fine or medium silk sutures, little if any imbrication being used

9 Closure of Scarpa's Fascia—Closure of Scarpa's fascia with small bites of the suture seems more sound anatomically and leaves less silk than does suture of the fat with large bites taken at random The sutures are preferably placed so that the knot will be down

10 Closure of the Skin—Interrupted mattress sutures of silk are advisable for this step The proper closure of the lower third of the wound inside the hair line is of especial importance

TABLE 1—*Sex of Patients*

	Number of Patients	Percentage
Male	286	97
Female	8	3
Total	294	100

TABLE 2—*Side on Which Hernia Occurred*

	Number of Patients	Percentage
Right	118	40
Left	102	35
Bilateral	74	25
Total	294	100

MATERIAL

With the use of the Cooper ligament technic as described, three hundred and sixty-seven hernias have been repaired during the past seven years The operations were done by one of us (H N H) and by fourteen members of the resident staff under his direction

Sex—The predominance of males in this series (97 per cent, as shown in table 1) reflects the usual sex difference, which is much exaggerated by the industrial occupations of the clientele

Side—The right side was operated on most often, as shown in table 2, while in 74 instances a bilateral repair was performed The table refers to this type of operation only, in several instances, especially early in the series procedures were done on the other side which are not listed In every such instance the operation through Cooper's ligament was performed on the side with the largest hernia For technical reasons a

Lotheissen operation on the left side is more difficult for a right-handed surgeon than a similar operation on the right side

Classification—As seen in table 3, the incidence of the various types of hernia represented is approximately that found in an average series except that there were a large number of patients with direct inguinal weakness and also a large number with recurrent hernia (usually following operations done elsewhere). The high incidence of direct hernias is partly due to the fact that early in the series, when the procedure was still viewed somewhat as an experiment, it was used especially for direct hernias. Later, however, it was used in all cases, and during one five year period one of us (H N H) used no other type of repair. Another reason for the large number of direct hernias is that with routine inspection of Hesselbach's triangle with the gloved index finger from inside we detected a large number of direct weaknesses that would otherwise go unnoticed. The large number of operations for recurrent hernia

TABLE 3—*Types of Hernia Represented*

Classification	Number of Hernias	Percentage
Simple indirect	169	45
Simple direct	85	23
Indirect and direct (saddle bag)	56	15
Femoral and indirect	8	2
Femoral and saddle-bag	3	1
Sliding	3	1
Incarcerated	6	2
Recurrent indirect	20	5.2
Recurrent direct	21	5.2
Recurrent femoral	1	0.3
Recurrent saddle bag	1	0.3
Total *	373	100

* Including several duplications

(forty-one, in seven of which there was reenforcement with strips of free fascia lata) represents the unusually high incidence of 11 per cent in the entire series of three hundred and sixty-seven operations. Many of the patients had been operated on more than once before. In 1 case our operation was the fifth done for a single femoral hernia. None of these hernias previously operated on have recurred after our operations.

Follow-Up Studies—Completion of the follow-up studies proved difficult because of wartime migrations and employment difficulties. As seen in table 4, slightly more than one third of the patients have been followed for more than two years. Many other patients reported excellent results by letter or were even seen afterward for other complaints by other physicians. However, for the purposes of this study the only follow-up observations included are those involving actual examination of the groin by a physician. Furthermore, if the 28 patients operated on less than two years before this paper was written and hence not eligible for inclusion because of incomplete follow-up are excluded, the percentage followed for over two years is raised from 35 to 39.

There have been three recurrences, as described in the following case reports

CASE 1—V M, a man aged 46 years, had a bilateral indirect inguinal hernia repaired by the original Halsted-I-Lotheissen method on Nov 26, 1940. The right side was repaired by an assistant resident and the left by one of us (H N H). A recurrence of the hernia on the right side was discovered in April 1942 (seventeen months after operation), and reoperation was performed on the twenty-eighth day of that month. At operation an indirect sac 2 cm in diameter was found, possibly because the internal ring had not been closed snugly enough.

CASE 2—Repair of an indirect inguinal hernia on the right side was done by one of us (H N H) on Sept 29, 1942. Soon afterward the patient joined the army, and in May 1945 (thirty-two months after operation) while jumping from a landing craft with a full pack in the Southwest Pacific he noted a pain in the right groin. Two months later a hernia recurring "at the lower angle of the wound" (a direct recurrence?) was repaired by an army surgeon.

TABLE 4—*Period of Follow-up**

	Number of Patients	Number of Hernias
Less than twelve months	164	197
Twelve to twenty four months	27	39
Two years	18	24
Three years	28	34
Four years	16	18
Five years	34	44
Six years	9	11
 Total	294	367
Number followed for over 2 years	103	121
Per cent followed for over 3 years	35	36
 Recurrence rate		
Per cent of cases followed for over 2 years	2.9	2.8
Per cent of total cases	1.0	0.8

* There were three recurrences, which occurred seventeen eighteen and thirty two months postoperatively; two were indirect recurrences, and one was a direct recurrence.

CASE 3—A Bassini-Lotheissen operation by an assistant resident physician for an indirect inguinal hernia on the left side was done on Dec 1, 1942. A recurrence was noted eighteen months later, and repair was carried out soon afterward. At the second operation there was no direct weakness, but a large indirect sac was present which according to the operator showed "no evidence of the indirect sac ever having been ligated."

There was 1 death in the hospital, described in the following report.

CASE 4—D M was a Negro aged 51 years. The weight was 276 pounds (125 Kg) and the height 71 inches (180 cm). There was an inguinal hernia on the left side extending over halfway from the groin to the knee. This was repaired by an original Halsted-I-Lotheissen procedure on June 3, 1944, by one of us (H N H). The patient died on the twelfth postoperative day of massive pulmonary embolism, a diagnosis which was proved at necropsy. (At the time of death the wound was found to be infected.)

It is of interest that in the 2 patients operated on by assistant residents the recurrences were indirect while in the other patient (operated on by H N H) the recurrence was direct.

The recurrence rate was 2.3 per cent for the cases followed for over two years and 0.8 per cent for the entire group of cases. In the group of 203 of these cases handled by one of us (H N H) there was one recurrence, giving a rate of 0.5 per cent. When this figure is corrected by the exclusion of the thirty-three operations done during the past two years (after which, of necessity, there was not a two year follow-up) the recurrence rate for the entire series is even less.

In the group of patients followed in whom there was no recurrence the incidence of pain and other subjective symptoms was roughly comparable to that in patients treated by other technics.

COMMENT

Anderson,³⁴ in discussing the causes of failure in repair of inguinal hernia, stated:

It is obvious that when the transversalis fascia is attached to Poupart's instead of Cooper's ligament an undesirable pocket is left. That is, the normal insertion and attachment of the transversus aponeurosis and transversalis fascia in this region is into the rectus sheath medially, then into the pubic bone and outward laterally into the ilio-pectineal line (Cooper's ligament). Since this is its normal insertion, this is where it should be attached when carrying out a repair. If, as has been commonly done, it is sewn to Poupart's ligament, a peritoneal trough-like pouch tends to form, the potential beginning of a recurrent hernia.

Then the Canadian writer goes on to say:

In the case of hernias and tires, there is a first line of defense, the transversalis fascia and the inner tube, respectively. We do not fasten the edge of the hole in the inner tube to the outer casing, no more should we fasten the edge of the transversalis fascia to the outer casing, the external oblique (Poupart's ligament), but rather to its own structure and insertion—Cooper's ligament.

The suture of the transversalis fascia or of the "conjoined tendon" to Cooper's ligament is, according to Brunkow,³⁵ "likened to pulling the curtain clear to the base of the window instead of only halfway for an effective blackout." The same procedure can also be compared with tucking the sheets in at the foot of the bed so that the toes of a tall person will not protrude.

Our studies bear out these theoretic advantages of the procedure. We do not believe that we have evidence that the Cooper ligament technic is infallible, or that it is better than other reputable methods or that it should be immediately adopted by all other operators. We do

³⁴ Anderson, R. Failures in Inguinal Hernia, *Canad M A J* **49** 392-396 (Nov) 1943

³⁵ Brunkow, B. H. Surgical Considerations of the Inguinal Triangles, *Am J Surg* **59** 594-597 (March) 1943

believe, however, that in our hands it has given good results and that we are justified in the continuation of its use

As to its scope at the present time, the technic seems to us to be the preferable one for the following types of hernia in the groin (1) recurrent hernia, (2) femoral hernia, (3) direct hernia and (4) indirect hernia in older patients in whom Hesselbach's triangle shows signs of weakness. The method would, on the other hand, seem to be superfluous for young patients with uncomplicated congenital indirect inguinal hernias.

SUMMARY AND CONCLUSIONS

A hernial repair based on the anatomic studies of McVay and Anson, who postulated that the transversalis and internal oblique fibers normally attach themselves not to Poupart's ligament but rather to Cooper's ligament, has been utilized which attempts to restore the normal attachments to the latter. In this operation, first advocated by Lotheissen for the repair of femoral hernia, no fascial layer is sutured to Poupart's ligament.

An identical procedure is used for all the main types of hernia of the groin—indirect inguinal, direct inguinal and femoral. The fact that only one technic need be learned may be another advantage of this method.

This technic has been used in the repair of three hundred and sixty-seven hernias of the groin of several types in 294 patients during a seven year period. Follow-up studies indicate that the results as well as the theoretic advantages justify the procedure. Of one hundred and thirty-one hernias in patients followed for two years or more, three have recurred (2.3 per cent), while for the entire series of cases the known recurrence rate is 0.8 per cent.

DISCUSSION

DR CHESTER MCVAY My own comment on the operative procedure should wait until I have my own series which is now almost complete. I thought this morning that I would simply show three slides to reemphasize something which Dr Harkins has already said.

(Slide) This is a view of the inguinal region with the external oblique muscle open, showing Hesselbach's triangle. These are the fibers of the transversalis going not to the inguinal ligament but to Cooper's ligament.

(Slide) The next slide is picked from another series showing the inguinal ligament completely away and the fibrous insertion passing over to the midline and showing the spermatic vessels down to Cooper's ligament.

(Slide) Dr Harkins said that this repair is used for all types of hernia. This oblique view of the inguinal region will demonstrate why it is applicable. The defect in a large indirect, direct or femoral hernia is a defect in the same layer. The problems are the same. For instance, an indirect hernia, as it enlarges, enlarges medialward, and in extremely large ones it compromises this area. A femoral hernia enlarges medially, and it compromises this area. A direct hernia is

definitely through this area. Except in the case of a very small indirect hernia, resuturing of the stronger layer above to Cooper's ligament reestablishes the normal anatomy. The steps outlined by Dr. Harkins I agree with perfectly.

DR. ROLAND F. MUELLER, Lincoln, Neb. I have been interested in the results obtained by Dr. Harkins with this procedure. Of 149 consecutive cases of hernia in which I have operated and which I have followed for the past six years, 15 were cases of femoral hernia. This is an incidence of 10 per cent, as compared with the usual incidence of 5 to 6 per cent given in the literature for femoral hernias. In the 149 cases, the McVay technic, using Cooper's ligament, was employed in 42. There were five recurrences among the 149, and two of these occurred among the 42 cases in which the Cooper ligament repair was used. The 2 patients were among the earlier ones operated on by this method, and I feel that with additional experience there will be fewer recurrences. It is curious to note that some of these patients do not know that they have a recurrence because it is so trivial and symptomless. One cannot always rely on correspondence as a method of follow-up. In fact, two of the above five recurrences were so trivial that the patients did not feel that they had a recurrence.

In the surgical repair of femoral hernia I feel that they should all be approached by this route—through the inguinal canal. There were no recurrences among the femoral hernias repaired, all five being recurrences of inguinal hernia.

The exposure of Cooper's ligament is not particularly difficult. Frequently one may be surprised by the fast dropping away of Cooper's ligament as one exposes it posteriorly and laterally, as compared with the course of the inguinal ligament. The one drawback to the use of Cooper's ligament as an anchor is the area of potential weakness remaining superior and lateral to the posterior suture placed in the ligament.

EFFECT OF DISTENTION OF THE BILIARY TRACT ON THE ELECTROCARDIOGRAM

Experimental Study

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A L MESSEY, M.D.

AND

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THE COEXISTENCE of disease of the biliary tract and disease of the heart is well known Willius and Brown¹ analyzed eighty-six unselected consecutive necropsies on patients with proved coronary sclerosis Chronic cholecystitis with or without cholelithiasis was present in 26 per cent Laird² found cardiac lesions in 77 per cent of a series of 65 patients with disease of the gallbladder In 109 cases of cholecystitis Schwartz and Herman³ found evidence of cardiac disease in 63 per cent An incidence of only 41 per cent was found in another 109 medical patients without clinically recognized disease of the biliary tract or cardiac disease

These and other reports show that there is an increased incidence of cardiac disorders in patients with disease of the biliary tract There are many physiopathologic factors common to the two diseases, such as age, disturbed metabolism, obesity, diet and infection

Surgical intervention for cholecystitis, cholelithiasis or choledocholithiasis has frequently resulted in improvement of an associated cardiac condition This has been manifested by relief from angina, recovery from decompensation and improvement or return to normal of the electrocardiogram (Fitz-Hugh and Wolferth,⁴ Wolferth,⁵ Ravdin, Royster

From the departments of surgery and medicine, Duke University Medical School and Hospital

1 Willius, F A, and Brown, G E Coronary Sclerosis An Analysis of Eighty-Six Necropsies, Am J M Sc. 168 165, 1924

2 Laird, S M The State of the Heart in Gall-Bladder Disease A Personal Investigation, Brit M J 1 884, 1938

3 Schwartz, M., and Herman, A The Association of Cholecystitis with Cardiac Affections A Study Based on One Hundred and Nine Cases, Ann Int Med 4 783, 1931

4 Fitz-Hugh, T, Jr., and Wolferth, C C Cardiac Improvement Following Gall Bladder Surgery, Ann Surg 101 478, 1935

5 Wolferth, C C Relationship between Biliary Tract Disease and Heart Disease, J Mt Sinai Hosp 8 1121, 1942

and Sanders,⁶ Moschcowitz,⁷ Clarke,⁸ Weiss and Hamilton,⁹ Laird,² Schwartz and Herman,³ Straus and Hamburger¹⁰ and McArthur and Wakefield¹¹)

Attacks of pain in the gallbladder or of colic may simulate attacks of angina pectoris or coronary occlusion since the pain is occasionally referred to a similar segmental distribution. The pain in disease of the gallbladder, however, is usually referred along the seventh and eighth thoracic spinal segments and is commonly right sided, whereas the pain in angina pectoris is commonly left sided and referred along the fifth to the eighth cervical spinal segments and the first to the fourth thoracic spinal segments. In angina pectoris the pain is frequently referred down the left arm and can be brought on by effort and relieved with nitroglycerin.

The electrocardiogram may not always aid in a correct diagnosis since intra-abdominal diseases such as cholecystitis, pancreatitis or perforated peptic ulcer have been reported to cause electrocardiographic alterations (Murphy and Livezeg,¹² Gubner,¹³ Scherf and Klotz¹⁴ and Gottesman, Casten and Beller¹⁵)

The abnormalities noted in these conditions are changes in the T waves in significant leads, slurring and notching of the QRS complexes and elevation or depression of the S-T segments.

6 Ravdin, I S, Royster, H P, and Sanders, G B Reflexes Originating in the Common Duct Giving Rise to Pain Simulating Angina Pectoris, Ann Surg 115:1055, 1942

7 Moschcowitz, E. The Electrocardiogram in Uncomplicated Disease of the Gall Bladder and the Changes Induced by Operation, J Mt Sinai Hosp 10:632, 1944

8 Clarke, W E Electrocardiographic Changes in Active Duodenal and Gall Bladder Disease, Am Heart J 29:628, 1945

9 Weiss, M M, and Hamilton, J E The Effect of Gall Bladder Disease on the Electrocardiogram, Surgery 6:893, 1939

10 Straus, D C, and Hamburger, W W The Significance of Cardiac Irregularities in Reference to Operability of Cholelithiasis, Cholecystitis and Duodenal Ulcer, J A M A 82:706 (March 1) 1924

11 McArthur, S W, and Wakefield, H Observations on the Human Electrocardiogram During Experimental Distention of the Gall Bladder, J Lab & Clin Med 30:349, 1945

12 Murphy, F D, and Livezeg, M M Electrocardiographic Changes Simulating Those of Acute Myocardial Infarction in a Case of Perforated Gastric Ulcer, Am Heart J 28:533, 1944

13 Gubner, R S Electrocardiographic Changes in Abdominal Disease, J A M A 124:122 (Jan 8) 1944

14 Scherf, D, and Klotz, S D Electrocardiographic Changes After Acute Loss of Blood, Ann Int Med 20:438, 1944

15 Gottesman, J, Casten, D, and Beller, A J Changes in the Electrocardiogram Induced by Acute Pancreatitis A Clinical and Experimental Study, J A M A 123:892 (Dec 4) 1943

With these findings at present a correct diagnosis is imperative since operation on a patient with coronary occlusion should be avoided also, in incorrect diagnosis of coronary insufficiency or coronary occlusion in a patient with disease of the biliary tract may result in making a cardiac invalid or a patient who would otherwise be relieved by appropriate surgical intervention. The correct diagnosis can usually be made by adequate elicitation of the patient's history, physical examination and correct roentgenologic and electrocardiographic interpretation.

There appears to be some confusion in the literature regarding the relationship of disease of the biliary tract and cardiac disease. It seems reasonable to us that patients who have disease of the biliary tract with an abnormal electrocardiogram should have in association coronary artery and myocardial disease.

A series of experiments were carried out to study the relationship of disease of the biliary tract and cardiac disease. These consisted of electrocardiographic studies of the effect of distention of the biliary tract in two groups of animals. The first group with normal hearts, served as controls. The second group had experimentally produced lesions of the coronary arteries.

EXPERIMENTAL METHODS

In all experiments adult male and female dogs were used. Light anesthesia was produced with the intravenous injection of chloralose the dose employed being approximately 0.1 Gm per kilogram of body weight. The choice of anesthetic is important since electrocardiographic changes and changes in the blood pressure may occur with the administration of ether, cyclopropane and the barbiturates.¹⁶ (See Underwood and Gavor¹⁶ and Gruber¹⁷)

A series of 5 dogs without cardiac lesions was used as a control group. Electrocardiograms were obtained before the induction of anesthesia with the animal resting on its back. Chloralose was then administered intravenously, and an electrocardiogram was taken with the animal under anesthesia. Through an incision in the right upper area of the abdomen the common bile duct was ligated with two hemi-tied silk ligatures close to the duodenum. Care was taken to ligate as low as possible and to ligate only the duct in order that the nerve plexuses would be undisturbed. A cannula is inserted in the fundus of the gallbladder and held in place by a purse string suture and ligature. A special manometer with a side tube for the introduction of 150 ml. solution of sodium chloride was attached to the cannula. The left common carotid artery was cannulated and prepared for kymographic tracing of the blood pressure.

Respirations were recorded on the kymograph with the use of a chest tambour. Heart rate, pulse, the changes in blood pressure and respirations were recorded at

¹⁶ Schaefer G D, Underwood F J and Gavor E P. The Action of Amytal on Increasing Vagus Cardiac Inhibitory Effects and of Ether in Increasing the Heart Rate After Its Depression by Amytal. Am J Physiol 91:461, 1929.

¹⁷ Gruber C M. The Barbiturates and the Thiobarbiturates. Some Differences in Their Actions When Administered to Human Beings and to Experimental Animals. JAMA 117:1447 (Oct 4) 1941.

, with varying degrees of pressure (5 to 560 cm of water) in the biliary tract at the end of the experiments the animals were subjected to autopsy. Additional animals without cardiac lesions were subjected only to ligation of common duct. Serial electrocardiograms were taken at intervals for periods of ten and twenty-two days to study the effect of chronic obstruction and e.

another series of 10 animals cardiac lesions were produced by injection of a strong solution of invert sugar about the left main descending coronary or by ligation of various branches of the left descending coronary artery ie circumflex arteries

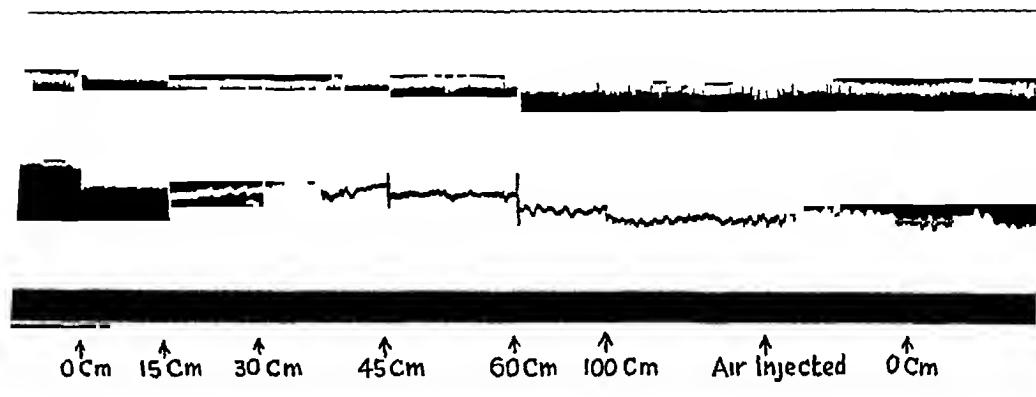


Fig 1—Kymogram on dog 3. Blood pressure and respirations with varying degrees of biliary pressure. Note the fall in blood pressure and respiratory changes with distention.

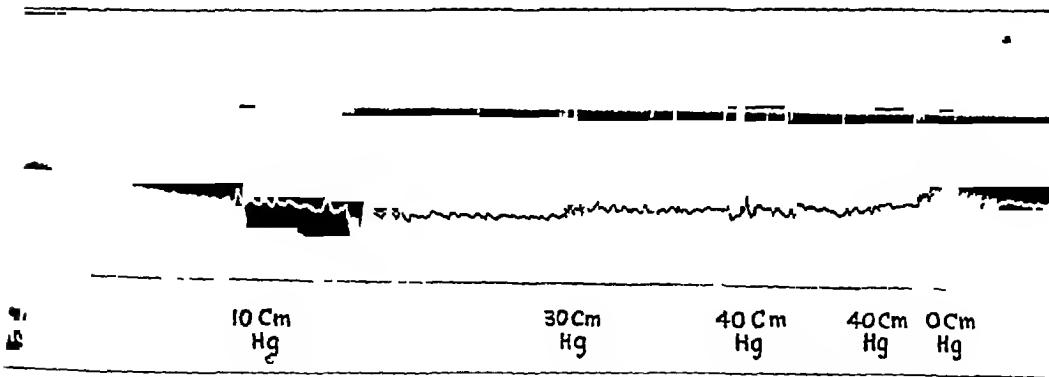


Fig 2—Kymogram on dog C-2 seventeen days after ligation of the coronary artery. Note the blood pressure and the respirations with varying degrees of biliary pressure.

Of this group, 3 animals died with ventricular fibrillation, 1 died in six hours and 2 in eight hours. Another animal died on the fifth postoperative day after disruption of the thoracotomy wound. Atropine and quinidine were employed intravenously in the 6 remaining animals to prevent ventricular fibrillation. In this group coronary lesions were produced by ligation in 5 and by injection in 1.

Intravenously administered chloralose with endotracheal positive air pressure was employed for the operative procedure. The heart was approached through

a 20 mm. incision made on the left anterior side in the fifth interspace. Incision was made of peritoneal injection of the coronary vessels was carried out.

ECG recordings were taken before and after anesthesia, with the chest open before and after ligation or injection of the coronary artery and at varying intervals thereafter for twelve to seventeen days until the biliary tract was cleared.

In 5 of the animals distention of the biliary tract was performed in the same manner as in the control group. Serial electrocardiographic tracings, blood pressure and respirations were recorded. In another animal ligation of the common bile duct was carried out after ligation of the coronary artery. The ligature around the common duct cut through, with reopening, which necessitated re-ligation.

TABLE I.—Results of Distention of the Biliary Tract in Control Dogs

	Biliary Tract Pressure On H ₂ O	Blood Pressure mm Hg	Cardiac Rate	Respirations with Distention	Electrocardiogram
Dog 1	Initial	5	200	140	No change except in rate
	After distention	100	140	135 with inspiratory difficulty	
	Final	0	140	170	
Dog 2	Initial	0	150	220	No change with distention
	After distention	100	150	220 with inspiratory difficulty	
	Final	0	160	215	
Dog 3	Initial	0	110	130	No change
	After distention	100	110	110 with inspiratory difficulty	
	Final	0	100	114	
Dog 4	Initial	0	100	115	No change except for increase in the cardiac rate
	After distention	100	60	270 with inspiratory difficulty	
	Final	0	100	270	
Dog 5	Initial	0	170	84	There was flattening of the waves in all leads but no deviation of the RS-T segment or junction
	After distention	100	91	160 with inspiratory difficulty	
	Final	0	100	100	

— 12 days later. Serial electrocardiograms were taken at intervals throughout this period. The animal was subjected to autopsy eleven days after the second ligation.

RESULTS

The results in the control group are summarized in table 1. In the 5 dogs subjected to acute biliary distention there were no significant changes in the electrocardiogram following distention other than variations in the cardiac rate (figs 3 and 4). In the 2 dogs in which chronic distention of the biliary tract and jaundice were produced by ligation of the common bile duct there were no significant electrocardiographic changes at the end of nineteen and twenty-two days (Buch-

) The pressures in the biliary tract were 30 and 45 cm of No blood pressure recordings or respiratory tracings were made.

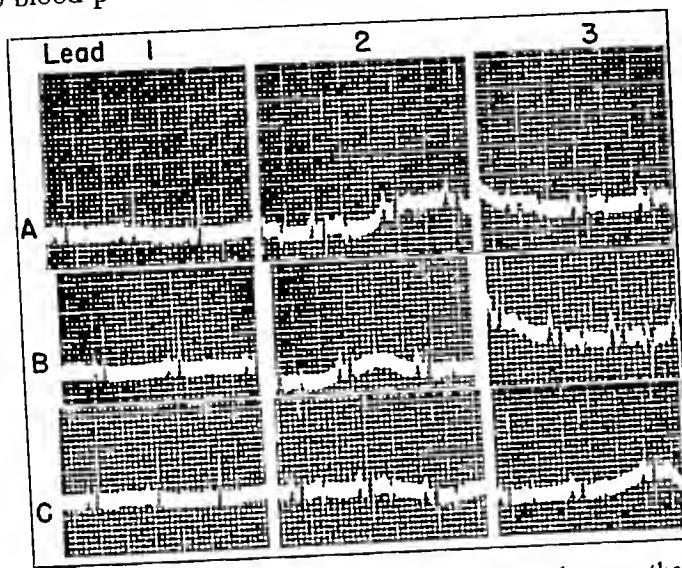


Fig 3.—Electrocardiogram on dog 3 (control) *A*, under anesthesia *B*, biliary distention with a pressure of 100 cm of water *C*, release of biliary pressure

o

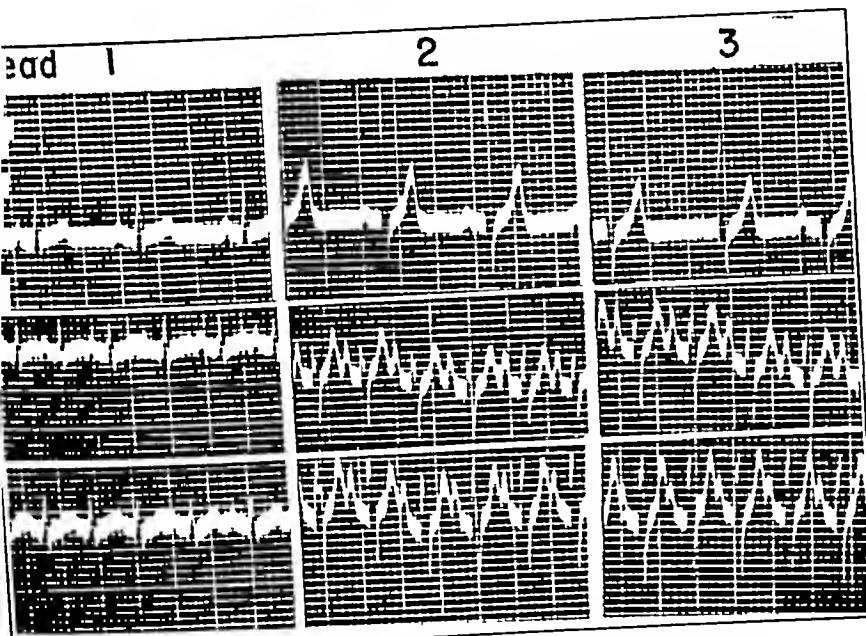


Fig 4.—Electrocardiogram on dog 4 (control) *A*, under anesthesia *B*, biliary distention with a pressure of 340 cm of water *C*, release of biliary pressure to zero. The cardiac rate was increased with distention, but there was no deviation of the RS-T segment.

The results of distention of the biliary tract in the dogs with lesions of the coronary artery are summarized in table 2. In dog C-1

TABLE 2.—*Results of Distention of the Biliary Tract in Dogs with Lesions of the Coronary Artery*

	Biliary Tract Pressure Cm H ₂ O	Blood Pressure, Cardiac Rate Mm Hg	Respirations with Distention	Electrocardiogram
Dog C-1—Thirteen Days after Injection of the Left Anterior Descending Coronary Artery (Infarction of the Anterior Wall, Left Ventricle)				
Initial	2.5	170	80	Inspiratory distress
After distention	400	110	81	slower and deeper
Final	0	110	81	
Dog C-2—Seventeen Days after Ligation of the Middle Branch of the Left Descending Coronary Artery (Infarction of the Posterior Lateral Wall, Left Ventricle)				
Initial	5	130	110	Inspiratory distress
After distention	540	96	180	slower and deeper
Final	0	130	180	
				With distention of the biliary tract there was marked sagging of the RS-T segments in leads II and III which did not return to the isoelectric line after distention was released
Dog C-3—Seventeen Days after Ligation of the Main Circumflex Branch of the Left Coronary Artery (Infarction of the Posterior Lateral Wall, Left Ventricle)				
Initial	5	128	140	Inspiratory distress
After distention	540	70	65	slower and deeper
Final	0	70	141	
				After distention the RS-T junction became elevated in all leads, with a notable increase in the height of the T waves
Dog C-4—Twelve Days after Ligation of the First and Second Circumflex Branches of the Coronary Artery (Infarction of the Posterior Wall, Left Ventricle)				
Initial	5	146	205	Inspiratory distress
After distention	540	110	180	slower and deeper
Final	0	140	200	
				After distention there was elevation of the RS-T junction with increase in the height of the T waves. After release of pressure the record returned to normal. Crushing the leg did not change the record
Dog C-5—Twelve Days after Ligation of the Anterior and Middle Branches of the Left Descending Coronary Artery (Apical Infarction)				
Initial	5	150	90	Inspiratory distress
After distention	540	120	150	slower and deeper
Final	0	150	184	
				After distention there was elevation of the RS-T junction with increase in amplitude of the T waves in all leads, which returned to normal after release of the pressure

there were no significant changes in the RS-T junction or segment. In dog C-2 there was considerable depression of the RS-T segment in leads II and III with distention of the biliary tract. After release of

the pressure the RS-T depression did not return completely to the isoelectric level. In dog C-3 there was no change in the electrocardiographic findings in regard to myocardial ischemia in man. In dog C-7 there was a pronounced elevation of the RS-T junction and a slight increase of the T waves. After release of pressure the records were the same as those taken before release. In dog C-4 there was no change in the electrocardiogram. In dog C-5 administration of 1 ml. of water caused changes from taking place. After the water there was some change in the RS-T junction but it was not marked.

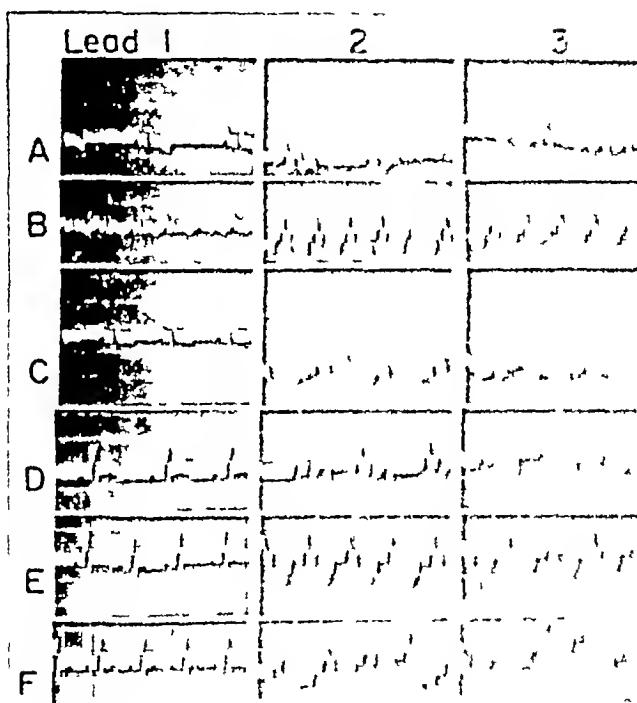


Fig. 5.—Electrocardiograms taken one hour after inflation of the balloon in dog C forty-eight hours after inflation, and again at the end of the experiment, seventeen days after inflation. The pressure of 540 cm. H₂O was maintained during the entire experiment. The change in the position of the RS-T junction and the change in the shape of the T waves are noticeable.

produced by urinary distension. The increased distention, the electrocardiogram, and the blood pressure were recorded.

The respiratory rate was measured in dog C-5. There was no change.

On the second day the animal was again anesthetized and the balloon inflated to a pressure of 540 cm. H₂O.

In control experiments there were no significant electrocardiographic changes after anesthesia with chloralose. Only minor variations consisting of changes in cardiac rate were noted.

In the control group pathologic examination of the various organs including the heart, liver and extrahepatic bile passages failed to reveal any abnormalities except in the 2 animals subjected to chronic obstruction. In these only the liver and bile passages showed changes characterized by dilated bile ducts and canalicular, with an intense

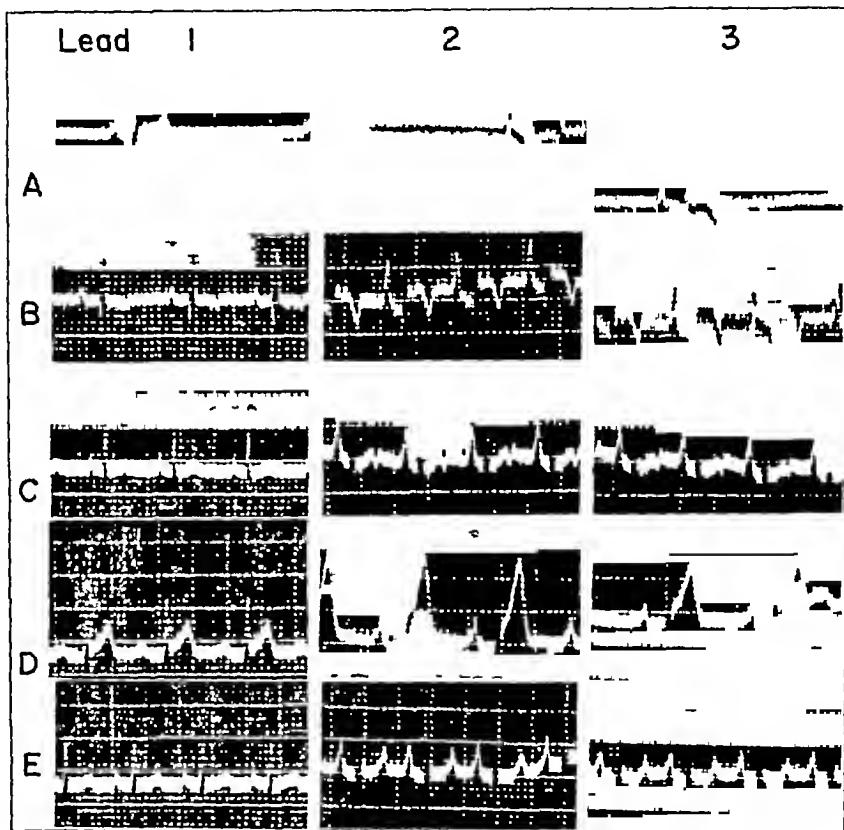


Fig 6.—Electrocardiogram on dog C-3. *A*, control. *B*, forty-eight hours after ligation of the main circumflex branch of the left coronary artery. *C*, under anesthesia seventeen days after ligation of the coronary artery. *D*, biliary distension with a pressure of 540 cm of water. Note the increase in amplitude in the T waves and the elevation of the RS-T junction with distension of the gallbladder. *E*, release of biliary pressure to zero.

periportal inflammatory reaction. The hepatic cells showed fatty degeneration with areas of central necrosis. Bile casts were present in many of the dilated ducts.

In the group subjected to coronary lesions, myocardial infarction with healing in various stages was demonstrated. The liver and the



found the T waves to be unstable in the normal dog and altered by manipulation of the heart without interfering with the coronary circulation. They found no significant modification of the RS-T segment. Harris and Hussey²³ found decided variability of the T waves in a study of 50 dogs, but in only 1 was there any deviation of the RS-T segment.

It is clear from the work of the aforementioned investigators that electrocardiographic changes in the dog do not parallel those found in man. Barnes and Mann, however, observed that ligation of the

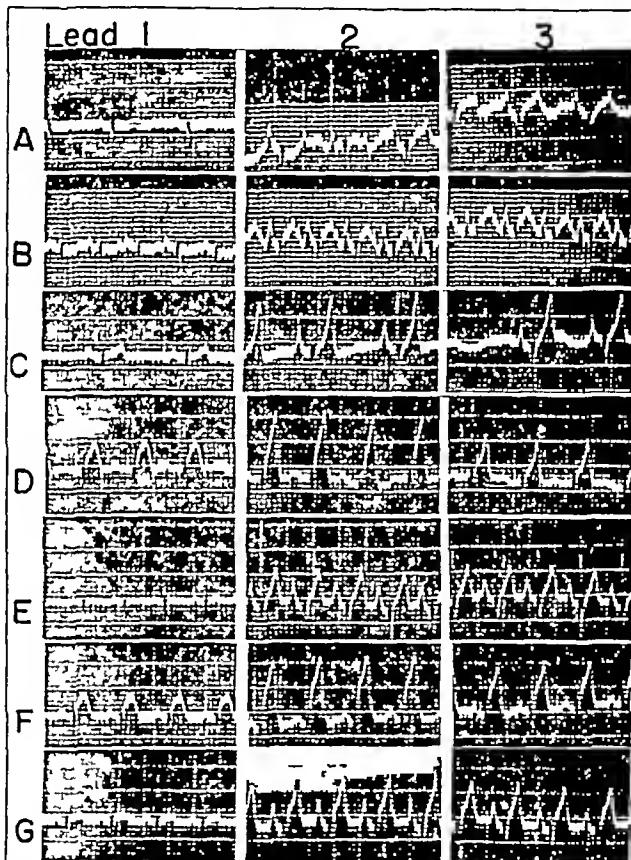


Fig 8.—Electrocardiogram on dog C-5. *A*, control. *B*, two hours after ligation of the anterior and middle branches of the left descending coronary artery. *C*, under anesthesia twelve days after ligation of the coronary artery. *D*, biliary distention with a pressure of 540 cm. of water. There was elevation of the RS-T junction and increased amplitude of the T waves. *E*, release of the biliary pressure to zero. *F*, distention of the gallbladder ten minutes after 1 mg. of atropine was administered intravenously. The findings are the same as in *D*. *G*, record taken after the testicles were crushed. There were only slight changes in the electrocardiogram resembling those observed with distention of the gallbladder.

²³ Harris, B. R., and Hussey, R. The Electrocardiographic Changes Following Coronary Ligation in Dogs, *Am Heart J* **12** 724, 1936.

the injection of 1 mg of atropine intravenously failed to prevent the changes in a single dog. Crushing the leg in 1 of the dogs did not produce any change in the electrocardiogram, however, crushing the testicle of another dog produced changes which resembled those accompanying distention of the biliary tract but which were of lesser degree. There were no significant changes in the blood pressure after the crushing of the testicles or the leg in these 2 animals.

SUMMARY

Distention of the biliary tract in dogs without a preexisting lesion of the coronary artery or the myocardium failed to produce any significant changes in the electrocardiogram.

Distention of the biliary tract in dogs after ligation of one or more of the coronary arteries produced abnormal deviations of the RS-T segments in the electrocardiogram.

It is obvious that the extensive dissections in the removal of the breast could account reflexly for some of the edema along the lines indicated by Homans.

Veal² has made an elaborate study of the venous circulation in patients with obstruction of the subclavian, axillary and bascavian veins and has suggested that swelling of the arm is due to obstruction of the axillary and subclavian veins caused by thrombosis, scar formation, angulation of the veins and that lymphatic stasis is a secondary result of the venous obstruction, which if prolonged will lead to progressive blockage of the lymph flow. He states that "we then have a condition similar to the 'milk leg' which follows thrombosis of the deep veins of the thigh and pelvis. Infection is prone to develop after lymphatic venous obstruction, and it may be the cause of further progressive blockage as well as an increase in the swelling."

Pure lymphatic edema is the least common form of edema seen after the removal of a breast, and the edema which is seen postoperatively in the swollen arm is really an admixture of venous obstruction, secondary lymph stasis and, apparently, a self-perpetuating mechanism dependent on the tonicity of the muscles and the irritability of the various vascular elements associated in the involved area.

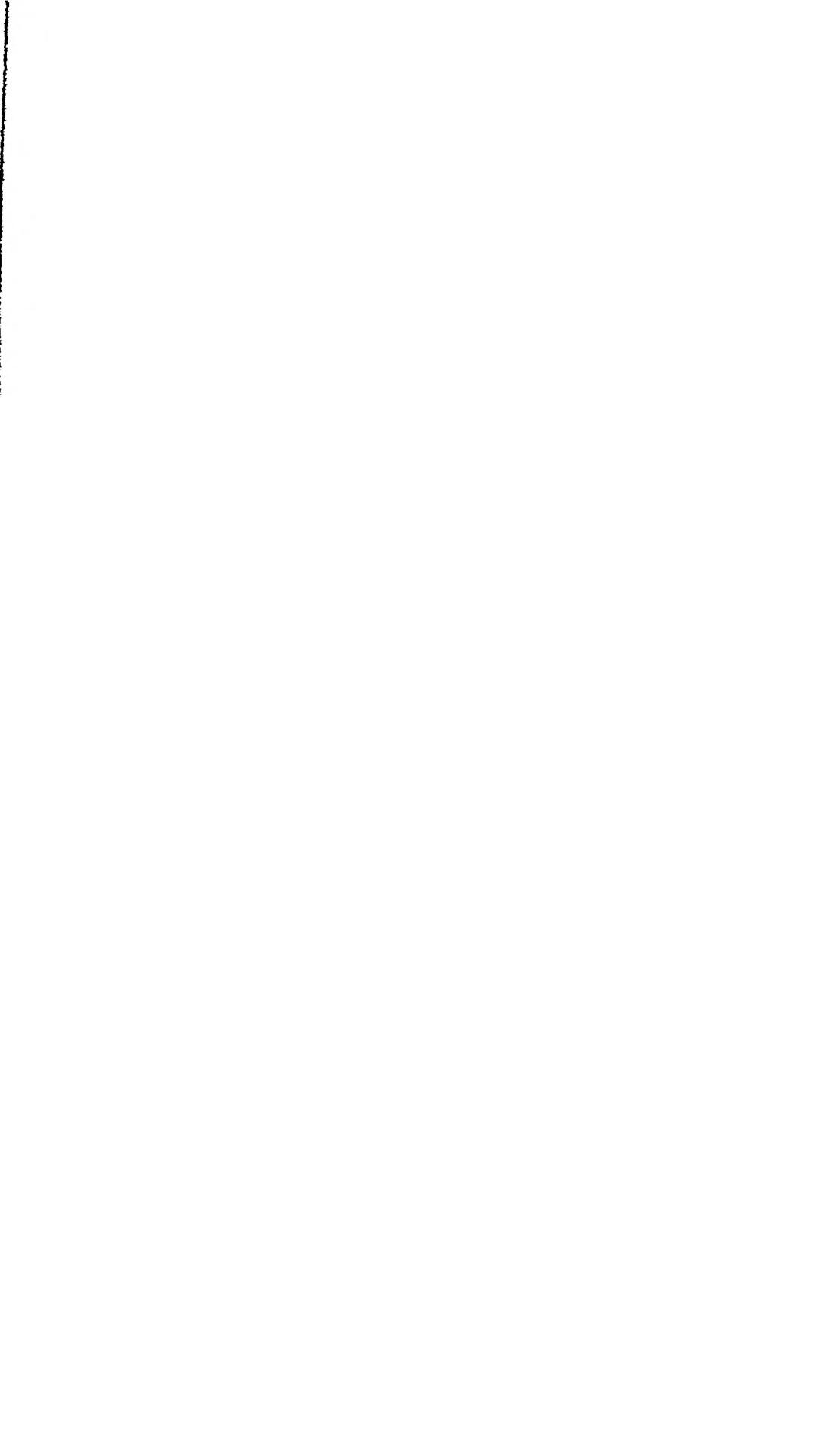
According to Lerche and Kumlin,³ clinical manifestations of thrombophlebitis are due to the establishment of a vasomotor reflex action of impulses originating in the thrombosed venous segment. They are of the opinion that there are three dominant factors in this syndrome: one the amount of vein involved, two, arteriolar spasm, and three, venospasm. The last factor is the most constant and significant.

The frequency and extent of thrombophlebitis in the involved arm subsequent to mastectomy have never been ascertained. How long it persists is not so important, since the mechanisms operating at the site of the trauma are presumably the same in all instances in which the arm becomes swollen after mastectomy. Ochsner and DeBakey⁴ were the first to call attention to the revolutionary teaching of Lerche and Kumlin, that the mechanism of development of the clinical manifestations of thrombophlebitis is the initiation of a vasomotor reflex action as a result of impulses originating in the thrombosed venous segment.

2 Veal, J. R. The Pathological Basis for Swelling of the Arm Following Radical Amputation of the Breast, *Surg., Gynec. & Obst.* 67:752, 1938.

3 Lerche, R., and Kumlin, J. Tratamiento inmediato de las flebitis operatorias por la infiltración novocainica del simpático lumbar, *Cron. Clin.* 33:389, 1934.

4 Ochsner, A., and DeBakey, M. Therapy of Phlebothrombosis and Thrombophlebitis, *Arch. Surg.* 40:208 (Feb.) 1940, Thrombophlebitis and Vasospasm in Production of Clinical Manifestations, *J. A. M. A.* 114:117, 1940.



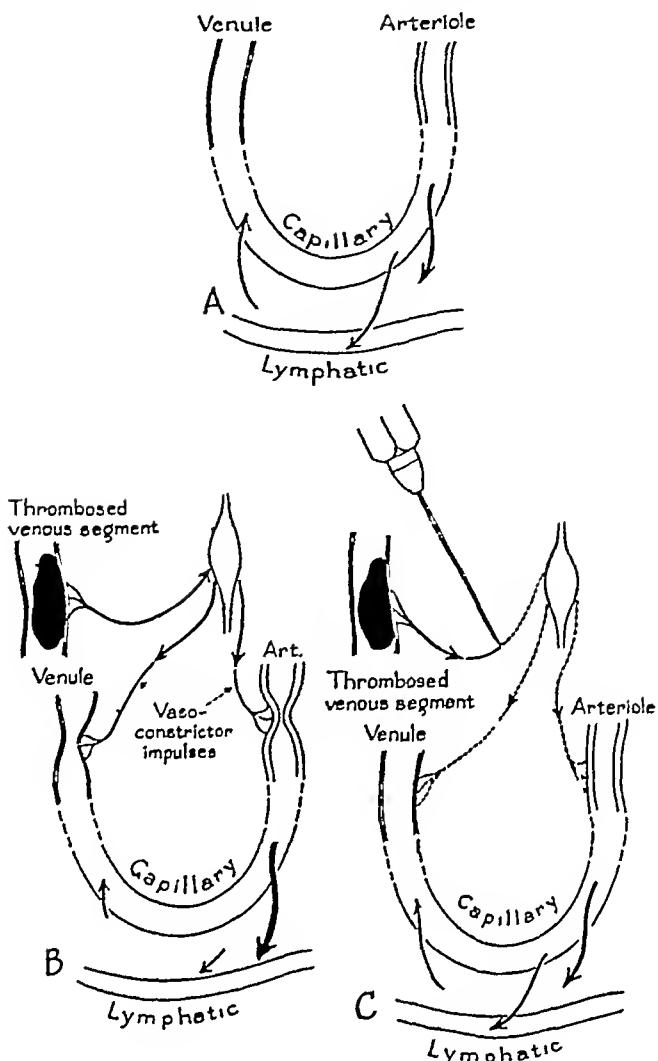


Fig 1.—*A*, diagram of normal physiologic relationship of intravascular and perivascular fluids. As indicated by the arrows, normally there exists a balance between the amount of fluids leaving the blood vessels and entering the tissues and that leaving the tissues and entering blood and lymphatic vessels (From Ochsner, A., and DeBakey, M. J. A. M. A. 114:117 [Jan 13] 1940). *B*, diagram of production of edema in thrombophlebitis. As shown by the arrows, the amount of fluids leaving the blood vessels and entering the tissues is greater than that leaving the tissues and entering the blood and lymphatic vessels. The increased transudation of fluids from the vascular system into the perivascular spaces is due to several factors. As a result of vasoconstrictor impulses initiated in the thrombosed venous segment there is produced a reflex vasospasm involving both the arteriolar and the venous elements of the vascular tree. Thus there occurs considerable increase in venous pressure, with consequent augmentation of filtration pressure and relative anoxia of capillary endothelium, both of which favor an increased transudation of vascular fluid into the perivascular tissues. The pronounced diminution of peripheral pulsations consequent to vasospasm and increased venous pressure results in a decrease in lymph flow and a stagnation of tissue fluids (From Ochsner, A., and DeBakey, M. J. A. M. A. 114:117 [Jan 13] 1940). *C*, diagram of the mechanism by which procaine hydrochloride block

tended veins is present, despite the fact that a great deal of the clinical picture may be secondary to obstruction of the venous flow

Devenish and Jessop have shown that the superficial and deep lymphatic vessels can be brought out strikingly with the intradermal injection of an 11 per cent solution of a dye which they call patent blue V. In the normal arm after an injection of a minute amount of the dye intradermally distinct streamer formation is present, in contrast to the affected limb, in which no streamer formation is present with an extensive diffusion of the dye and the skin of the forearm becomes gradually discolored by a fine bluish network, giving the impression that the dye was seeping through a spongelike mass.

Temperature readings taken at various levels on the affected limb reveal that it is usually from one-half to one degree colder than the uninvolvled arm. Measurements of the affected limb show an average increase of 1 inch (2.5 cm) or more as compared with the uninvolvled limb.

REPORT OF CASES

An analysis of 25 cases of postoperative swelling of the arm following mastectomy is herewith presented. Of the 25 patients involved, 21, or 85 per cent, had a block of the sympathetic nerves done on the affected side, 11 having it once, 5 having it twice, 2 having it three times and 4 having it four times. The number of times depended on the patient's ability to report for the procedure (factors being age, distance from the hospital and inclement weather). Both the anterior and the posterior approaches were used for the blocks, however, because of the multiplicity of minor complaints the posterior approach was abandoned, and the anterior or supraclavicular approach to the stellate ganglion was used exclusively.

A careful interrogation of the patient was made as to the onset of the symptoms subsequent to the mastectomy, whether or not she had preoperative or postoperative irradiation and whether or not any temperature or sensory disturbances were present in the arm before the operation. Careful measurements of the circumference of both arms were made 5 inches (12 cm) above and 5 inches below the olecranon process. Dermatherm readings were made for both arms and all corrections for room temperature carefully recorded.

IMMEDIATE EFFECT OF THE PARAVERTEBRAL BLOCK

Subsequent to the injection of 5 cc of a 1 per cent solution of procaine hydrochloride into the stellate ganglion on the affected side 20, or 96 per cent, of the patients noted an immediate feeling of warmth in the arm, and the average rise in temperature as demonstrated by the dermatherm readings was 4 degrees. Increased flexibility, relief of pain and a decrease in paresthesia and hypesthesia were noted in all instances.

SUBSEQUENT EFFECTS OF THE PARAVERTEBRAL BLOCK

The persistence of the subjective improvement was noted in 80 per cent of the patients. Subjectively, the feeling of warmth was manifested in all but 1 of them. The greatest improvement was noted in those who had two or more injections.

There was a pronounced disparity between the subjective improvement and the objective temperature readings and the reduction in the size of the arm after the paravertebral block. In 10, or 47 per cent of the patients who had block there was no reduction in the measurements. Eleven, or 53 per cent manifested only an average reduction of three fourths of an inch (2 cm), which, however, in itself is insignificant since 80 per cent showed persistent improved flexibility, increase in temperature and improved motion of the affected limb. The rises in temperature noted represent readings taken from two to seven days after the block. This is interesting because it supports the contention of Lerche and Kumlin that the responses of the temperature are at times out of proportion to the amount of procaine hydrochloride used and that the persistent response can sometimes be obtained with minimal doses of the drug. That the manifested persistent temperature response appears small is probably due to the insulating effect of the edema and the tissue fibrosis, which tends to inhibit the response.

The patient's impression of the type of therapy used is worthy of comment, since the satisfaction of the patient is an indication of the success of the treatment. Nineteen or 90 per cent, reported that they were benefited by the treatment. One patient (5 per cent) was guarded in her comment, however, she did say that the response was fair. Another patient was noncommittal in her response despite the fact that some objective improvement was present.

Of the 4 control patients who did not have a paravertebral block and who were observed for the same period (six months), none exhibited any improvement of the arm as compared with those who had it one or more times (table).

SUMMARY AND CONCLUSIONS

The injection into the stellate ganglion of 5 cc of a 1 per cent solution of procaine hydrochloride at periodic intervals will help to relieve the symptoms referable to swelling of the arm following mastectomy.

Over 80 per cent of the patients treated revealed subjective and objective clinical improvement after the paravertebral block.

Sixty per cent manifested an average reduction of three fourths of an inch (2 cm) in the size of the involved extremity.

No improvement was noted in patients who did not have paravertebral block.

Analysis of Twenty-Five Cases of Postoperative Swelling of the Arm Following Mastectomy

Case	No of Times Block Was Done	Subjective Response			Objective Response				
		Feeling of Warmth	Relief of Pain	Flexibility	Sensory Improve- ment	Dermatherm Reading	Persistent Temperature Response, Degrees	Tactile Improve- ment	Reduction in Measure- ment, Inches
1	3	+++	+++	+++	++++	2	1½	+++	¾
2	2	+++	+++	+++	++++	1	++	++	¾
3	1	+++	+++	+++	++++	1	++	++	0
4	2	+++	+++	+++	++++	1	++	++	½
5	4	+++	+++	+++	++++	1	++	++	0
6	1	+++	+++	+++	++++	1	++	++	++
7	4	+++	+++	+++	++++	2	+	++	0
8	2	+++	+++	+++	++++	1	++	++	0
9	3	+++	+++	+++	++++	1	++	++	1
10	1	+++	+++	+++	++++	1	++	++	++
11	3	+++	+++	+++	++++	1	++	++	1
12	1	+++	+++	+++	++++	1½	++	++	0
13	1	+++	+++	+++	++++	1	++	++	1
14	1	+++	+++	+++	++++	1	++	++	0
15	1	+++	+++	+++	++++	1	++	++	½
16	1	+++	+++	+++	++++	1	++	++	0
17	2	+++	+++	+++	++++	1	++	++	0
18	4	+++	+++	+++	++++	1	++	++	½
19	1	++	++	++	++	0	+	+	+
20	1	0	0	0	0	0	0	0	0
21	1	+++	++	++	++	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0

NEUROVASCULAR SYNDROME OF THE ARM ASSOCIATED WITH HYPERTROPHIED SUBCLAVIUS MUSCLE

Report of a Case, Including Operative Treatment

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DYSFUNCTION of an upper extremity due to pressure on vascular and nerve elements in the region of the shoulder are not uncommon and are extremely disabling. The scalenus anticus syndrome is well recognized and is frequently treated surgically with good result. The syndrome of thrombosis of the axillary vein is perhaps less well recognized, and its treatment is commonly entirely conservative in nature. It may be present with or without actual thrombosis. Various functional and mechanical factors have been suggested as of etiologic significance. Perhaps the most commonly accepted opinions have implicated the structures in the area of the clavicle and first rib (Aschoff,¹ Lohr,² Willan,³ Loewenstein,⁴ Gould and Patey,⁵ Picagli,⁶ Veal and McFetridge,⁷ Sampson and others⁸ and Judovich and others⁹)

1 Aschoff, L Thrombose und Embolie, Verhandl d gesellsch deutsch Naturf u Aerzte **83** 344, 1916

2 Lohr, W Ueber die sogenannte "Traumatische" Thrombos der Vena axillaris und subclavia, Deutsche Ztschr f Chir **214** 263, 1929

3 Willan, R J Three Cases of Axillary Vein Obstruction, Edinburgh M J **20** 105, 1918

4 Loewenstein, P S Thrombosis of the Axillary Vein An Anatomic Study, J A. M A **82** 854 (March 15) 1924

5 Gould, E P, and Patey, D M Primary Thrombosis of the Axillary Vein A Study of Eight Cases, Brit. J Surg **16** 208, 1928

6 Picagli, G Trombosi da sforzo della vena ascellare destra, Chir d org di movimento **19** 186, 1934

7 Veal, J R, and McFetridge, E M Primary Thrombosis of the Axillary Vein An Anatomic and Roentgenologic Study of Certain Etiologic Factors and a Consideration of Venography as a Diagnostic Measure, Arch Surg **31** 271 (Aug) 1935

8 Sampson, J J , Saunders, J B de C M, and Capp, C S Compression of the Subclavian Vein by the First Rib and Clavicle, with Special Reference to the Prominence of the Chest Veins as a Sign of Collateral Circulation, Am Heart J **19** 292, 1940

9 Judovich, B , Bates, W, and Brayton, W Pain in the Shoulder and Upper Extremity Due to Scalenus Anticus Syndrome, Am J Surg **63** 377, 1944

muscles, especially about the shoulders. There was moderate dilatation of the veins of the left arm and shoulder. The left hand and forearm became cyanotic when the arm was dependent, with the cyanosis most pronounced on the hand and wrist and shading off to a fairly normal color above the elbow. The left hand was definitely colder than the right. With elevation, the cyanosis slowly disappeared in three to five minutes and the hand and arm blanched more and more and remained cold. There was definite weakness of the left arm and hand (60 to 75 per cent) as compared with the right. The patient was able to elevate the arm just to an angle of 90 degrees but was unable to hold it there for more than a few seconds. It then slowly and steadily fell despite evident effort. There was slight palpable prominence of the sternal end of the clavicle, with a small notch at the junction of the shaft and the sternal enlargement. The radial pulse was of good quality but was completely obliterated with elevation of the arm to an angle of 40 degrees. It then again gradually became apparent at an elevation of about

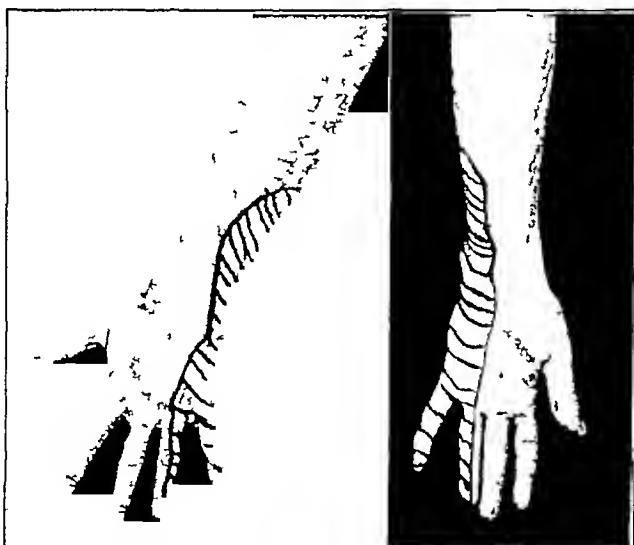


Fig 1.—Photograph of the area of hypesthesia conforming well to ulnar distribution

70 degrees, but was obliterated at an elevation of 90 degrees. There was definite hypesthesia in the ulnar distribution of the hand (fig 1).

Venographic studies were performed, 20 cc. of "diodrast" being used. Roentgenograms were taken after injection of 10 and 20 cc. and fifteen seconds after completion of the injection. Because of the complete block still present a fourth one was taken, approximately ten minutes after the development of the previous three. This showed a complete obstruction still present, with moderate collateral filling of the veins (fig 2).

Operative Report and Postoperative Course.—On May 30, 1945, a modified incision was made for exploration of the brachial plexus (fig 3) with the use of local anesthesia. As the fascia over the deltopectoral groove was incised it was noted that the cephalic vein was markedly distended. As it was followed upward to its point of transit through the coracoclavicular fascia, it was noted that there were two definite bulbous dilatations, which were evidently proximal to valves in the vein. The coracoclavicular fascia was incised, without any evident release of

the pressure. In order to expose the clavicle, the origin of the pectoralis major muscle was separated subperiosteally from the clavicle. The cephalic vein was found to pass between the edges of the pectoralis minor and subclavius muscles to empty into the subclavian vein, which was also found to be markedly distended. As the dissection was carried out, an enlarged subclavius muscle, appearing to be two to three times the usual size (about 30 cm in diameter) rolled up from beneath the clavicle as though squeezed out under pressure. As the subclavius rolled outward it was noted that distention of the cephalic and axillary veins was released. The brachial plexus, the subclavian and axillary arteries and the subclavian and axillary veins were carefully explored from well above the clavicle to below the point of insertion of the pectoralis major, and no other unusual condition was noted. With the subclavius muscle out from beneath the clavicle, it was possible to insert the index finger between the clavicle and the first rib and the vein and artery filled and emptied normally. With the muscle in its normal position, it was possible to get only the tip of the fifth finger between it and the rib and distention of the vein became apparent.

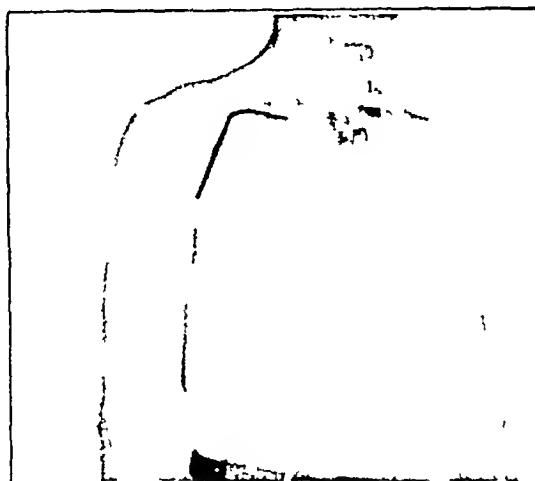


Fig 2.—Incision outline. This is not the patient in the case under consideration, but the incision is an exact replica of the one made therein.

The sternoclavicular joint was then explored. There was posterior displacement of the clavicle to about 3 mm. Elevation of this was considered but it was not performed. The subclavius muscle was incised at the point at which the vein passed beneath it, and the edge of the muscle was sutured to the anterior periosteum of the clavicle to keep it from being pushed back beneath the clavicle. (A segment of muscle should have been removed for better clearance and for pathologic examination.) The fascia only of the pectoralis major was sutured to the periosteum at the anterior edge of the clavicle.

The patient's postoperative course was surprisingly satisfactory. Within twenty-four hours he stated that the arm was improved, but it was thought that this was due to the support of the arm by the bandages and sling. However, after removal of all support the relief continued. For the first two weeks the hand still became slightly cyanotic when dependent, but the veins were no longer distended and the patient had discomfort for only a few minutes on two occasions. By this time he was able to lie on the involved side without discomfort.

A venogram was made on the seventeenth postoperative day. Care was taken to have the arm in the same position as at the previous examination. At this examination there was no obstruction fifteen seconds after cessation of injection (fig 4).

The first realization that a good result was to be expected came when, on return from a pass, the patient proudly exhibited his left thumb swollen from fracture of the metacarpal induced when he struck an opponent with the involved fist on the seventeenth postoperative day. His statement was that at no time during the four years since injury had he been able to get his arm up and strike with it, let alone do it quickly enough so that his opponent was unable to duck or hard enough

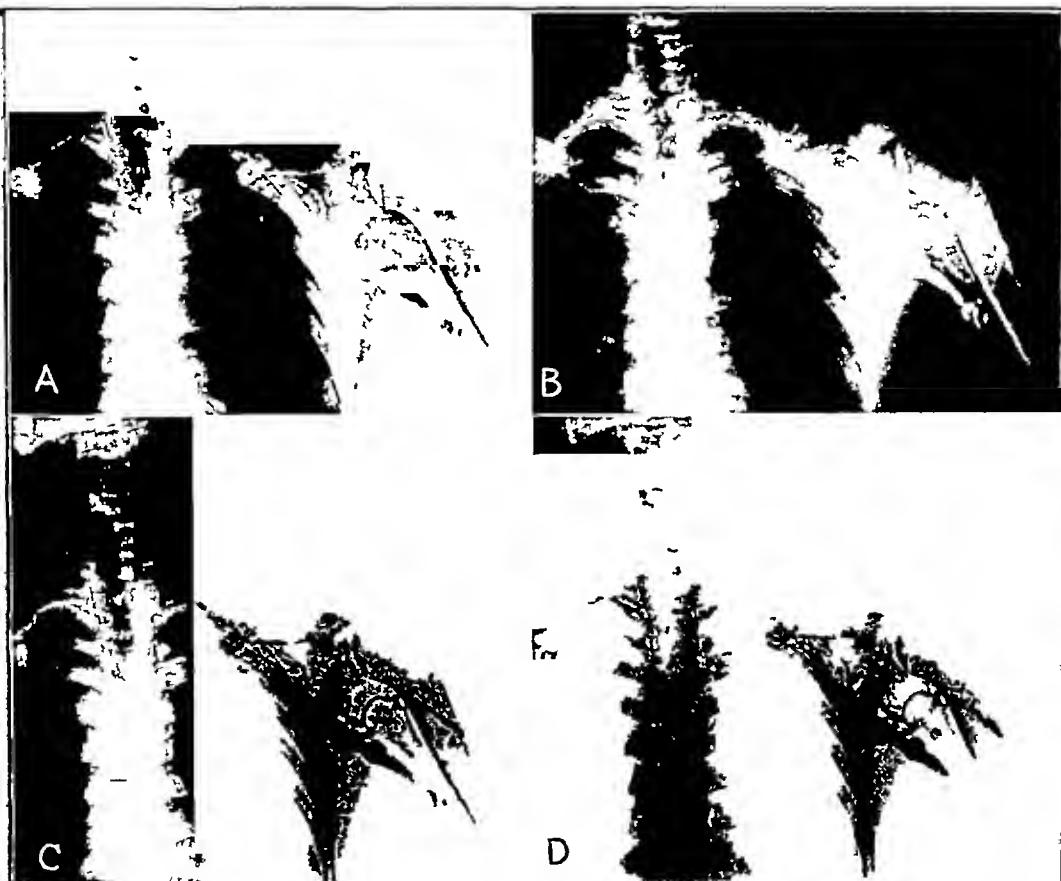


Fig 3.—Preoperative venogram. *A*, after injection of 10 cc. of "diodrast"; *B*, after injection of 20 cc. of "diodrast"; *C*, fifteen seconds after cessation of injection; *D*, ten minutes (approximately) after cessation of injection.

to make an impression. He was given a thirty day furlough, and on his return the condition of the hand and arm was about the same. He stated that he had had pain for a few minutes only on one or two occasions during the furlough.

Final examination was made before his discharge from the hospital five months after operation. The veins were not distended, and the hand and forearm no longer became cyanotic. The pulse was no longer obliterated on elevation of the arm. There was no difference in the temperature of the two upper extremities. The left hand and arm did not blanch on elevation. The strength of the left

extremity had definitely increased, and it was now 85 to 90 per cent as strong as the right extremity. He could raise the arm to an angle of above 140 degrees and could maintain it at an angle of 90 degrees for more than ten minutes. The prominence of the sternal end of the clavicle remained. Sensation was normal in the hand. These findings were checked by the men in each specialty, except for the consultants, who had made the preoperative examination. A third venogram made just before discharge of the patient, failed to show obstruction. The patient was again examined in June 1946 and in January 1947. He is now working as a clerk, and the only difficulty encountered has been in placing or moving heavy articles on shelves high above the head when it is done repeatedly without rest. The condition has remained the same as it was at the time of discharge.

COMMENT

Thrombosis of the axillary vein has been reported and the symptomatology carefully described repeatedly since the first credited report

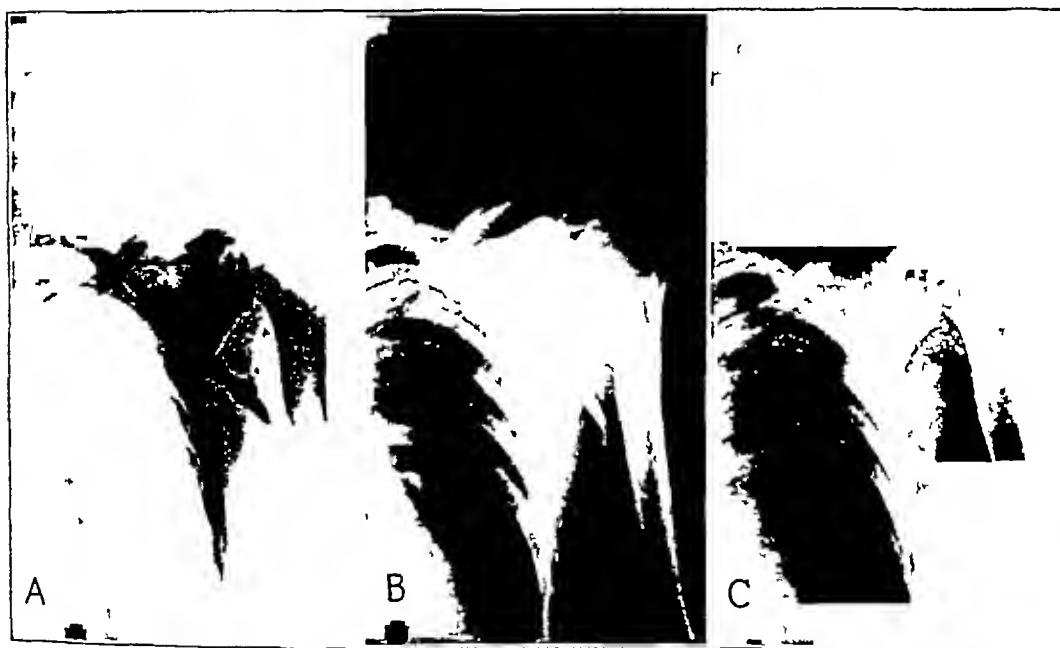


Fig 4.—Postoperative venogram *A*, after injection of 10 cc of "diodrast"; *B*, after injection of 20 cc of "diodrast"; *C*, fifteen seconds after cessation of injection.

by Von Schrotter.¹⁰ Excellent reviews and case reports have been given by Willan,³ Matas,¹¹ Veal¹² and others. Although the mor-

10 von Schrotter Erkrankungen der Gefäße, in von Nothnagel, H. Specielle Pathologie und Therapie, Vienna, Alfred Hölder, 1894, vol 15, pt 3, p 533.

11 Matas, R. Primary Thrombosis of the Axillary Vein Caused by Strain, Am J Surg 24:642, 1934.

12 Veal, J. R. (a) Thrombosis of the Axillary and Subclavian Veins, Am J M Sc 200:27, 1940, (b) Thrombosis of the Axillary and Subclavian Veins with a Note on the Post-Thrombotic Syndrome, Am Heart J 19:292, 1940.

tality from this disease is minimal, the morbidity is a serious factor, especially since in the majority of cases it occurs in men who do relatively heavy work and are bread-winners. The early loss of time from work with an acute attack may be prolonged for weeks to months or even years with the chronic state. Individual cases in which there has been prolonged disability have been reported by Jeanneny and Mathey-Cornat,¹³ Baum,¹⁴ Firth and Mackay,¹⁵ Mason,¹⁶ McGoogan and Simmons,¹⁷ McClanahan,¹⁸ Clute,¹⁹ Ballon,²⁰ Swindt²¹ and Anderson.²²

In an excellent discussion of the entire problem Matas¹¹ reported a case followed for four years in which there was residual disability. Gould and Patey⁸ reported on 8 cases, of which 5 were followed. Four of the 5 patients had persistent symptoms of varying severity, 1 having them for six months, 1 for four years, 1 for five years and 1 for an unstated length of time after onset of the disease. The fifth patient reported no complaints. Veal^{12b} followed 7 of 9 cases of phlebothrombosis and thrombophlebitis of the axillary vein for two months to twenty-two years. All the patients involved had weakness, early fatigue and pain after prolonged work or exercise.

Although in many instances actual thrombosis of the vein has been shown to be present (Paggi,²³ Guyot and Jeanneny,²⁴ Grimault and

13 Jeanneny G, and Mathey-Cornat, R Thrombo-phlebite dite par effort du membre supérieur, *J de méd de Bordeaux* **101** 858, 1924

14 Baum, H L Die traumatische Venenthrombose an der oberen Extremität, *Deutsche med Wchnschr* **39** 997, 1913

15 Firth, D, and Mackay, R Primary Thrombosis of the Axillary Vein with Recurrence, *Lancet* **2** 679, 1932

16 Mason, J M Clinics Primary Thrombosis of the Axillary Vein Caused by Strain, *Internat Clin* **1** 239, 1938

17 McGoogan, T S, and Simmons, E E Effort Thrombosis of the Subclavian Vein in the Puerperium, *Nebraska M J* **18** 283, 1933

18 McClanahan, B V Primary Thrombosis of the Axillary Vein, *Am J Surg* **30** 459, 1935

19 Clute, H M Idiopathic Thrombosis of the Axillary Vein, *S Clin North America* **11** 253, 1931

20 Ballo, H C Primary Thrombosis of the Axillary Vein, *Canad M A J* **32** 414, 1935

21 Swindt, J K Traumatic Thrombosis of the Upper Extremities, *California & West. Med* **27** 635, 1927

22 Anderson, O Venography in Case of So-Called Traumatic Thrombosis of Axillary Vein, *Acta radiol* **19** 126, 1938

23 Paggi, B Trombosi venose da sforzo degli arti superiori, *Policlinico (sez chir)* **40** 383, 1933

24 Guyot, J, and Jeanneny, G Thrombo-phlebite dite "par effort" de la veine axillaire Examen anatomopathologique (Sabrazes), *Bull et mem Soc de chir de Paris* **49** 231, 1923

Dantlo,²⁵ Chifolian and Folliasson,²⁶ Huard²⁷ and Lapeyre²⁸), in others the same syndrome has been present without thrombosis (Moure and Martin,²⁹ Cottalorda,³⁰ Lohr² and Hammann³¹) The mechanism responsible in the cases without thrombosis has usually been considered to be spasm secondary to trauma. The presence of this syndrome with or without actual thrombosis has been attributed to many factors. Von Schrotter¹⁰ considered it to be due to stretching of the axillary vein, while Cadenat³² felt that distention of the vein by respiratory effort was responsible. However, pressure of various structures in the area about the clavicle and the first rib has been most frequently suggested as the causative factor (Aschoff,¹ Lohr,² Loewenstein,⁴ Gould and Patey,⁶ Picagli,⁹ Veal¹² Veal and McFetridge,⁷ Sampson and others⁸ and Judovich and others¹⁰). Willan⁸ suggested that the vein suffered injury against the first rib and that the intima was damaged, which determined the occurrence of a thrombus. Loewenstein⁴ believed that the pressure by the costocoracoid ligament and subclavius muscle on the axillary vein distended by the forced expiration which characterizes effort resulted in venous stasis. His excellent drawings of anatomic dissections of the shoulder area show these pressure points with various positions of the arm. Picagli⁹ likewise felt that the syndrome was due to the anatomic relations in the region of the costocoracoid ligament. Sampson, Sanders and Capp⁸ suggested that the compression of the subclavian vein occurred between the first rib and the clavicle and that this pressure was increased by the subclavius muscle and the deltopectoral fascia. They furnished convincing evidence to support their additional contention that this was more likely to occur in a special structural type, i.e., persons with high, horizontally curved first ribs and with the clavicle directed upward and backward. More recently,

25 Grimault, L., and Dantlo, R. Thrombo-phlébite dite "par effort" de la veine axillaire, *Presse méd* 5 10, 1924

26 Chifolian, M T, and Folliasson, A. Thrombo-phlébite à streptocoques du membre supérieur droit. Guérison rapide par résection segmentaire de la veine axillaire thrombose, *Presse méd* 40 84, 1932

27 Huard, P. Thrombo-phlébite du membre supérieur gauche révélée par un effort. Résection du segment veineux thrombose, dénudation arterielle, *Presse méd* 42 556, 1934, Bull et mém Soc nat de chir 59 1406, 1933

28 Lapeyre, J L. A propos de la thrombo-phlébite dite par effort, *Rev de chir* 52 229, 1933

29 Mouré, P., and Martin, R H. A propos de la thrombo-phlébite par effort, *Presse méd* 20 371, 1932

30 Cottalorda, J. La thrombo-phlébite par effort, Lyon chir 29 169, 1932

31 Hammann, W. Zur Kenntnis der sogenannten Achselvenenthrombose (Claudicatio venosa intermittens der oberen Extremität), *Zentralbl f Chir* 67 1871, 1940

32 Cadenat, F M. Les thrombophlébites du membre supérieur, *Paris méd* 35 253, 1920

Wright³³ has also implicated these structures and also the subscapularis muscle and has supported his opinion with anatomic dissections.

The most convincing evidence that pressure points are involved has been furnished by those workers who used injection methods. Gould and Patey,⁵ using cadavers, injected plaster of paris into the cubital veins with the arm abducted. In 1 instance a shallow groove corresponding to the costocoracoid ligament was shown and in 2 others a broad deep groove corresponding to the subclavius muscles. Injection studies on living patients for various purposes have shown similar defects. Sampson,³⁴ during an injection with "diodrast" for visualization of the heart, obtained roentgenograms which showed a defect of a like nature just proximal to the first rib. He also reported a similar observation by Robb and Steinberg,³⁵ in whose patient, incidentally, the typical syndrome of thrombosis of the axillary vein developed after the injection as though to add emphasis to the findings. In studies of this particular area Veal and McFetridge⁷ observed the same defect, which they considered to be due to pressure of the subclavius muscle.

The possibility that there is a close anatomic relationship between the scalenus anticus syndrome and the syndrome of obstruction of the axillary vein has been considered by Veal^{12a} and by Judovich and others.⁹ They suggested that both may be caused by spasm of the scalenus anticus muscle, which, according to the latter, draws up and holds the first rib so as to compress the artery, vein and nerves against the subclavius muscle and the clavicle. Judovich and his colleagues reported on 2 patients with dilatation of the veins of the shoulders and arms, 1 of whom at operation had dilatation of the vein lateral to the first rib. One patient had symptoms for two years and the other for fifteen years, and both showed gradual improvement after section of the scalenus anticus muscle. The cases of Falconer and Weddell,³⁶ discussed later, might also be considered to be in this category.

In the presently recorded case the flow of opaque medium was found to stop at a point just lateral to the clavicle and first rib, and the obstruction was practically complete, with much filling of collateral veins. This is the usual position of obstruction, the second commonest region being in the area of the subscapularis tendon. At exploration the obstruction was shown to be due to narrowing of the space between the clavicle and the wall of the chest. This narrowing, it was felt,

33 Wright, I S. Neurovascular Syndrome Produced by Hyperabduction of Arms, *Am Heart J* 29: 1, 1945.

34 Sampson, J J. An Apparent Causal Mechanism of Primary Thrombosis of the Axillary and Subclavian Veins, *Am Heart J* 25: 313, 1943.

35 Robb, G P., and Steinberg, I., cited by Sampson³⁴.

36 Falconer, M A., and Weddell, G. Costo-Clavicular Compression of the Subclavian Artery and Vein Relation to the Scalenus Anticus Syndrome, *Lancet* 2: 539, 1943.

was due to hypertrophy of the subclavius muscle plus slight posterior displacement of the clavicle as a result of the original injury. The deltopectoral and costocoracoid ligaments, which many authors have considered to be of importance in this syndrome, were not shown to have any real significance in the present case.

Treatment of the syndrome of obstruction of the axillary vein has been largely conservative, with rest and elevation during the acute stage and suggestion of change of occupation for the post-thrombotic syndrome. This has not been entirely satisfactory because of the great loss of time from work and the fact that many persons with this syndrome are unable to get work requiring less effort. In a few cases surgical treatment has been undertaken. Cures have been reported by thrombectomy or by excision of a segment of the vein in the acute stages. Paggi²³ found and excised the thrombotic portion in 28 cases, with good result. Stabins²⁴ more recently has reported a good early result from ligation and resection of the axillary vein. Other cases in which excision of the thrombotic segment was carried out have been reported by Guyot and Jeanneney,²⁵ Grimault and Dantlo,²⁶ Chifolian and Folliason,²⁷ Huard²⁸ and LaPeyre²⁹. Moure and Martin²⁹ reported a cure after exploration in a case in which they found no thrombus or actual occlusion but rather a collection of serum and edema in the area of the injury. Cottalorda³⁰ reported a cure by exploration in a case in which there was no thrombus but in which the vein was in a state of rigid spasm. Ochsner and DeBakey³¹ reported 2 cases in which cure was effected by sympathetic block.

In the presently reported case there was no thrombosis shown at operation, and as a result resection was not considered. Since it was a late case, mere exploration could not be expected to give a satisfactory result. However, a simple procedure, i.e., section of the subclavius muscle to relieve the pressure on the vein, artery and nerves, gave a satisfactory result. It is hoped that in future cases the syndrome may be treated by similar simple procedures in order to improve the known serious morbidity of this condition. It would seem reasonable to suspect that if the operation were carried out early, before permanent fixation of secondary responses, the results might be satisfactory. Sympathetic block should first be tried in early cases because of its simplicity and the good results obtained by Ochsner and DeBakey³².

Falconer and Weddell³³ treated several patients with scalenus-anticus-like syndrome with compression of the subclavian artery and vein. In the first case a segment of the first rib was removed from beneath the

37 Stabins, S. J. Primary Thrombosis of the Axillary Vein Due to Strain, U. S. Nav. M. Bull. 41: 1106, 1943.

38 Ochsner, A., and DeBakey, M. Therapy of Phlebothrombosis and Thrombophlebitis, Arch. Surg. 40: 208 (Feb.) 1940.

artery, with excellent result. In the second case a cervical rib was present. The scalenus anticus muscle was first incised, but there was still pressure on the lower cord. The tip of the cervical rib was then removed, but pressure remained although it was lessened. In the third case compression of the lower trunk of the brachial plexus against the first rib by a tendinous band was revealed, which was relieved by section of the band.

It is possible that in the occasional case of scalenus anticus syndrome in which cure is not brought about by section of the scalenus anticus muscle there may be a syndrome present similar to that in these cases and in the presently reported one. Differentiation could be made first by observation of the evidences of venous pressure, although in an occasional case the vein passes over the insertion of the scalenus anticus and could be compressed (Gray³⁹ and Judovich and others⁹), second by injection of procaine hydrochloride into the scalenus anticus, as suggested by Falconer and Weddell²⁶ and Judovich and his colleagues, and third by careful observation at operation of the involved structures and the extremity before and after section of the scalenus anticus muscle.

CONCLUSIONS

The syndrome of so-called thrombosis of the axillary vein is of importance because of the serious morbidity.

It is likely that a predisposing cause lies in an unusual anatomic relationship, with narrowing of the costoclavicular space, and/or enlargement and hypertrophy of the subclavius muscle and hypertrophy of the costoclavicular fascia or, in some instances, of the subscapularis muscle.

Diagnosis is made by observance of the typical symptoms and signs and by venographic study, which gives a typical picture of obstruction of the flow of opaque medium usually in the region of the clavicle and first rib and of filling of collateral channels.

Treatment has been conservative in most instances. Operation is believed to be justified in a larger number of cases in view of its relative simplicity and the consistently good results reported.

A case of so-called post-thrombotic syndrome is reported in which considerable improvement followed the relief of pressure by section of the subclavius muscle.

³⁹ Gray H. Anatomy of the Human Body, ed 24, Philadelphia, Lea & Febiger, 1942, p 665.

PRECAUTIONARY ADMINISTRATION OF PENICILLIN IN SURGICAL PROCEDURES ON BONES AND JOINTS

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DURING the course of a project¹ on the use of penicillin in the treatment of chronic osteomyelitis, recommended by the Committee on Medical Research and contracted for by the office of Scientific Research and Development with the Hospital for Joint Diseases, the opportunity arose for the initiation and the subsequent development of several collateral studies. All these were briefly discussed in the report² submitted at the official termination of the project, and others³ were subsequently reported with additional data in greater detail. This paper concerns itself with the use of penicillin as a precautionary measure against infection during the course of surgical procedures with primary closures of the wounds of bones and joints on (1) patients without osteomyelitic lesions, (2) patients with inactive osteomyelitic lesions, (3) patients with active infections and (4) patients with postoperative infections. These studies were closely coordinated with studies on the bacteriologic status of the wounds and the penicillin concentration in the blood and urine.

PENICILLIN IN SURGICAL PROCEDURES ON NONOSTEOMYELITIC PATIENTS

At the onset of the project, when the supply of penicillin was limited, the drug was used only in the treatment of clean surgical wounds when the operative field became contaminated or when the patient was subjected to undue trauma. In those instances 20,000 units of penicillin was administered intramuscularly every three hours immediately after

1 Buchman, J., and Blair, J. E. Penicillin in the Treatment of Chronic Osteomyelitis. A Preliminary Report, Arch. Surg. 51: 81-92 (Sept.) 1945.

2 Buchman, J., and Blair, J. E. Report on the Use of Penicillin in the Treatment of Staphylococcal Infections with Special Reference to Acute and Chronic Osteomyelitis and Several Collateral Studies, Bull. Hosp. Joint Dis. 6: 114-125 (Oct.) 1945.

3 Blair, J. E., Carr, M., and Buchman, J. The Action of Penicillin on Staphylococci, J. Immunol. 52: 281-292 (Nov.) 1946. Buchman, J., and Blair, J. E. The Use of Absorbable Substances to Obliterate Bone Cavities and as Hemostatic Agents in Bone and Joint Conditions, J. Bone & Joint Surg., to be published.

TABLE 1.—Administration of Penicillin in Surgical Procedures on Patients Who Did Not Have Osteomyelitis

Case	Comment
1	Exploration for herniated nucleus pulposus and Hhah's fusion of the lumbosacral area of the spine reenforced by tibial "clothespin" graft, operative field contaminated by oil leaking from motor saw healed per primam
2	Open repair of extensively comminuted fracture of patella patient aged and in poor general condition with unexplained fever and comminuted fracture of shoulder post operative pneumonia and stormy convalescence healed per primam
3	Open reduction of pathologic (marble bone) fracture of shaft of femur and fixation with Townsend Gilfillan plate healed per primam
4	Open reduction and fixation with Thompson Z nail of extensively comminuted inter trochanteric fracture of neck of femur subjected to severe surgical trauma, spontaneous drainage of sterile hematoma on 14th postoperative day complicated by phlebitis of internal saphenous vein healed on 40th day
5	Open reduction of dislocation of elbow and fracture of neck of radius subsequent to severe trauma incidental to manipulation on two occasions under anesthesia and complicated by unexplained rise in temperature, healed per primam
6	Interinnominoabdominal amputation for osteogenic sarcoma superimposed on Paget's disease of pelvis with obstruction of rectum and urethra, complicated by postoperative slough of part of flap away from incision due to embarrassed circulation, incision healed per primam
7	Interinnominoabdominal amputation for recurrent osteogenic sarcoma of stump of thigh, healed per primam save for slough of flap as in case 6
8	Excision of epiphysial plate of neck of femur for epiphyseolysis and unsuccessful attempt at nailing with Thompson Z nail, healed per primam
9	Open dislocation of malaligned head and neck of femur with replacement of head and fixation with ivory peg, healed per primam (same patient as in case 8)
10	Intra-articular arthrodesis and fixation of hip with 2 Thompson Z nails for osteoarthritis, healed per primam
11	Inlay tibial bone graft for fixation of symphysis pubis for disruption of pelvis incidental to parturition, healed per primam
12	Translocation osteotomy and fixation with reverse Neufeld nail for ununited fracture of neck of femur no plaster of paris immobilization, patient was turned on opposite side on 1st postoperative day, and operative site was completely disrupted, skin sutures held healed per primam
13	Nail removed and parts realined and immobilized in plaster of paris spica, shaft slipped, healed per primam (same patient as in case 12)
14	Fracture site (hip) exposed parts realined and fixed with stainless steel screws and immobilized in plaster, nonunion occurred, healed per primam (same patient as in case 13)
15	Colonna reconstruction operation, healed per primam (same patient as in case 14)
16	Arthroplasty of hip for osteochondritis disseccans, healed per primam
17	Interscapulothoracic amputation for sarcoma of coracoid process healed per primam
18	Prolonged exposure of forearm for repair of nerves because of causalgia and paralysis of hand repair could not be performed healed per primam
19	Amputation through forearm, healed per primam (same patient as in case 18)
20	Repair of ulnar nerve and tendon—3½ hours healed per primam
21	Biceps femoris transplantation healed per primam
22	Triple arthrodesis of foot and transplantation of peroneus longus tendon, healed per primam (same patient as in case 21)
23	Synovectomy of knee for chronic hydroarthrosis, healed per primam
24	Secondary arthrotomy of knee for excision of scar from osteochondritis disseccans, chondromalacic areas of patella and femur and internal semilunar cartilage healed per primam
25	Arthrotomy of knee completely disorganized from an old infection for removal of loose bodies, semilunar cartilages and exostoses healed per primam
26	Arthrotomy of knee for removal of discoid meniscus and parameniscal cyst healed per primam
27	Biopsy and disarticulation of hip for osteogenic sarcoma, healed per primam save for small areas of skin necrosis due to embarrassed circulation
28	Excision of comminuted head of radius and capitellum healed per primam
29	Open reduction and fixation of humerus with Townsend Gilfillan plate, healed per primam
30	Open reduction and fixation of fracture of neck of femur with Thompson Z nail following recovery from lobar pneumonia, healed per primam
31	Translocation osteotomy of femur and fixation with reverse Neufeld nail for ununited fracture of neck of femur healed per primam
32	Excision of fractured olecranon and fixation of triceps tendon healed per primam
33	Arthroplasty of hip and insertion of vitallium head and neck prosthesis for Marie-Strumpell disease, healed per primam
34	Obturator nerve resection healed per primam (same patient as in case 33)
35	Open reduction of comminuted intertrochanteric fracture of neck of femur and fixation with Neufeld nail healed per primam
36	Intra-articular and extra-articular arthrodesis of hip for poliomyelitis, healed per primam save for 2 small stitch abscesses
37	Intra-articular and extra-articular arthrodesis of Charcot hip and fixation with Thompson Z nail healed per primam
38	Translocation osteotomy and fixation with reverse Neufeld nail for Charcot hip, healed per primam (same patient as in case 37)
39	Open lengthening of right tendo Achilles for spastic paralysis healed per primam
40	Open lengthening of left tendo Achilles for spastic paralysis, healed per primam (same patient as in case 39)

the operation and for about ten days thereafter. As the supply of the antibiotic became less limited, it was administered to patients undergoing extensive operative procedures in which a complicating infection would have been disastrous. When the supply of the drug became plentiful, its administration was extended to practically all patients undergoing operative procedures. The technic evolved consists of the intramuscular administration of 20,000 units of penicillin every three hours day and night for twenty-four hours before the surgical procedure and for ten days thereafter. At the termination of the operative procedure, as each layer of tissue is sutured, the wound is flooded with an isotonic solution of sodium chloride containing 250 units of penicillin per cubic centimeter of the solution. Gauze soaked in the same solution is used for a dressing over the wound.

Table 1 lists all the operative procedures, forty-one in number, which have been performed under the conditions just described. Not a single infection occurred in this series notwithstanding the fact that in some instances there were actual contaminations of the field of operation, in others there were undue traumas before, during or after the operation, in others the procedures were unduly prolonged and in still others the procedures were of great magnitude. The only wound which broke down (case 4) was incidental to a large hematoma which was sterile. In several instances flaps or edges of skin underwent necrosis because of impaired circulation rather than because of infection.

It would therefore appear, in view of the complete avoidance of infections in the series of cases presented in table 1, that the intramuscular administration of penicillin for twenty-four hours before an operative procedure on bones and joints and for about ten days after and the local application of penicillin to the operative wound constitute a dependable method for the avoidance of the ordinary surgical infections which have plagued patients and embarrassed surgeons from time to time.

PENICILLIN IN SURGICAL PROCEDURES ON PATIENTS WITH INACTIVE OSTEOMYELITIS

Surgical procedures were performed on patients who had been subject to chronic osteomyelitic lesions of long standing, many of them multiple in distribution. All the lesions were apparently inactive at the time of the performance of the operations listed in table 2. Nevertheless, we would have deferred most of these procedures because of the history of relatively recent activity in all these instances were it not for the use of penicillin. In none of these instances was there any flare-up of the preexisting infections. The regimen consisted of the intramuscular administration of 20,000 units of penicillin every three hours for twenty-four hours preceding the operation and for approximately ten days thereafter. In addition, 250 units of penicillin per cubic centimeter of

isotonic solution of sodium chloride was used to flood the wound during the various stages of closure. None of the wounds was drained.

Though the series of instances is limited in number, it would nevertheless appear from the experiences with these patients and with those to be described in the next section that surgical procedures, with closure of the wounds, may be performed without the fear of recurrence of recent infections when the procedures are carried out under antibiotic control.

PENICILLIN IN SURGICAL PROCEDURES ON PATIENTS WITH ACTIVE INFECTIONS

The previously reported demonstration⁴ of the high frequency of healing by primary intention of extensively saucerized chronic osteomyelitic

TABLE 2.—Administration of Penicillin in Surgical Procedures on Patients with Inactive Osteomyelitis

Case	Comment
1	Excision of scar and skin plastic for recurrent ulcerations of scar of tibia incidental to sauerization operation, healed per primam
2	Excision of scar and translocation of fibula for nonunion of tibia secondary to infected compound fracture, healed per primam
3	Excision of spur of os calcis at site of a previous sauerization for chronic osteomyelitis, healed per primam
4	Vitallium cup arthroplasty of left hip for ankylosis in a patient with multiple quiescent osteomyelitic lesions, healed per primam
5	Vitallium cup arthroplasty of right hip for ankylosis in the presence of multiple quiescent osteomyelitic lesions, healed per primam (same patient as in case 4)
6	Resection of the left obturator nerve and removal of exostosis of malleolus which was the site of an osteomyelitic lesion, healed per primam (same patient as in case 4)
7	Resection of the right obturator nerve, healed per primam (same patient as in case 4)
8	Quadricepsplasty for limitation of motion incidental to long-standing chronic osteomyelitis, healed per primam

wounds treated under penicillin control has led us to perform surgical procedures with primary closures and without drainage notwithstanding the presence of active infection elsewhere in the body, whether the infection is distant or in close proximity to the operative site. The technic evolved consists of the use of 20,000 units of penicillin intramuscularly every three hours for twenty-four hours before and ten days after the operation and 250 units of penicillin per cubic centimeter of isotonic solution of sodium chloride to flood the operative wound at the various stages of closure without drainage. Gauze soaked in the penicillin-sodium chloride solution is used as a dressing for the wound. In instances in which the invading organisms are resistant, correspondingly larger doses of penicillin are utilized intramuscularly and locally. In none of the cases reported in table 3 have the secondary invaders ("nuisance organisms"), even though they were resistant to penicillin, interfered with the healing by primary intention.

4 Buchman and Blair (footnotes 1 and 2)

A review of table 3 indicates that convalescence was greatly shortened in that operative procedures were not postponed until infections elsewhere in the body were eliminated. Secondary operative closures have been eliminated through the avoidance of guillotine amputations, and the

TABLE 3.—*Use of Penicillin in Surgical Procedures on Patients with Active Infections*

Case	Comment
1	Callander amputation with primary closure and rubber tissue drain for an extensive osteomyelitis of the tibia and fibula with lymphedema and circumferential ulceration of the lower half of the leg flaps in close proximity to ulceration healed per primam
2	Resection of the fifth toe and distal two thirds of the fifth metatarsal bone and closure of the wound without drainage for osteomyelitis in a diabetic patient, healed per primam
3	Resection of the third and fourth toes and distal portion of the third metatarsal bone for perforating ulcers under third toe and third metatarsal in a diabetic patient, previous operative site (case 2) well healed, healed per primam
4	Amputation of the middle part of the forearm through edematous area containing many thrombosed vessels and primary closure with silk-worm gut drain for gangrene subsequent to operative reduction of a dislocated shoulder in the presence of persistent drainage from the shoulder wound healed per primam several small superficial areas of necrosis of the skin developed final healing in 136 days but elbow joint, which in other circumstances would have been sacrificed was preserved
5	Amputation through junction of middle and upper thirds of leg with primary closure for chronic osteomyelitis of tibia and large indolent ulcer, anterior flap bordered on ulcer healed per primam by primary closure & possible loss of the knee joint or at best an inadequately short stump was avoided
6	Arthrotomy of the left knee for the removal of para articular and intra articular osteocartilaginous bodies and an intra articular exostosis which left a large dead space in the presence of an infected ulcer on the right leg healed per primam
7	Resection of the third toe and metatarsal bone for chronic osteomyelitis healed per primam
8	Amputation through midportion of proximal phalanx of index finger for gangrene which followed self treatment skin flaps bordered on gangrenous area healed per primam making possible the preservation of a useful stump
9	Arthrodesis of hip for congenital dislocation in the presence of a draining sinus at site of the Steinmann pin in lower end of the same femur healed per primam
10	Amputation of the midleg through the site of a previously active chronic osteomyelitis of long duration and an adherent scar with the flaps bordering on a persistent ulcer healed per primam save for a small area of dry necrosis over site of old scar
11	Skin plastic and shortening of stump (15 cm) for recurrent ulceration of 10 months' duration from irritation of prosthesis over atrophic skin, healed per primam, preservation of an effective stump below the knee would not have been contemplated without antibiotic control (same patient as in case 11)
12	Amputation of the left midcalf for tuberculosis of foot with large open wound healed per primam
13	Amputation of the right midcalf for tuberculosis of lower 2 inches of the fibula ankle joint and os calcis with sinuses and swelling above the ankle joint healed per primam
14	Amputation of the midcalf for chronic osteomyelitis of tibia with large ulcer over lower third of leg and circumferential trophic disturbance of skin flaps bordered on ulcer, healed per primam (same patient as in case 13)
15	Neurolysis of musculospinal nerve and open reduction of fracture of midportion of humerus and fixation with a Townsend-Gilligan plate in the presence of a pressure sore with a necrotic base over anterior aspect of the elbow on the same side healed per primam
16	Lukas shelf operation for pathologic dislocation of hip subsequent to destruction of head and neck of femur in the presence of a roentgenographically active though clinically quiescent osteomyelitic lesion in the upper half of the same femur healed per primam
17	Callander amputation for spreading gangrene of the forefoot in an 86 year old patient with arteriosclerosis complicated by diabetes healed per primam

possibility of the performance of the ablations, with primary closure and without drainage, in close proximity to the site of disease has made possible the preservation of neighboring joints, which otherwise would have of necessity been sacrificed.

PENICILLIN IN POSTOPERATIVE INFECTIONS OF BONES
AND JOINTS

The group of cases presented in table 4 is limited in number and represents an accumulation over three and one-half years. Four of the patients were operated on by other surgeons. A review of these cases reveals no encouraging evidence pointing to the effectiveness of penicillin as the sole mode of therapy in the treatment of the postoperative infections described. In the first 4 cases the patients were treated in the days when the penicillin supply was greatly limited, and they may therefore possibly be excluded from consideration on the ground that the dosage was inadequate and that the length of therapy was insufficient. The remaining patients, on the other hand, were treated with adequate amounts of the antibiotic over a sufficient period.

In case 5 a penicillin-resistant organism was present, which would have required a blood level of penicillin not obtainable in ordinary circumstances. The flooding of the operative wound with a concentration of 250 units of penicillin would in all probability have been more than sufficient to prevent the development of the infection in that case. In 2 of the remaining cases the lesions contained penicillin-sensitive organisms. The clinical courses of these lesions were not different from those of lesions in which the sensitivities of the organisms were not determined. One may therefore conclude that the resistance of the organism to the influence of the antibiotic is not the deciding factor in the ineffectiveness of the drug under the given conditions.

The failure of penicillin as the sole mode of therapy to modify the course of the postoperative infection is readily understandable if one takes into consideration the inherent nature of the lesion. It is similar to the usual "surgical infection" in contrast to the "medical infection." The latter is characterized by an inflammatory process, with little or no necrosis of tissues. The lesion therefore remains in communication, or even may be in closer communication, with the blood stream because of the increased blood supply to the part and may therefore be influenced by therapeutic agents within the stream. A "surgical infection," on the other hand, is characterized by an inflammatory process on which there is superimposed multiple thrombotic phenomena, necrosis, suppuration and a walling-off process which greatly diminishes and eventually shuts off the blood supply to the local lesion so that therapeutic agents contained within the blood stream may become ineffective because of inability to reach the lesion. In the early phases of the surgical infection, before the tissues become thrombosed and necrotic, penicillin therapy may be effective. From these considerations it becomes evident that the timing of the administration of penicillin is the crux of the situation.

The early phases of postoperative infection presumably occur at the time of the surgical procedure and soon thereafter, when no appreciable

TABLE 4.—*Use of Penicillin in Postoperative Infections of Bones and Joints*

Case	Comment
1	A severe postoperative infection following Hibb's fusion of the lumbosacral area of the spine with a double 'clothespin' tibial bone graft associated with pneumonia and bacteremia caused by coagulase positive <i>Staphylococcus aureus</i> , with subsequent break-down of both wounds, was treated with 60,000 units of penicillin daily intravenously for 5 days and 12,500 units in daily local dressings. Treatment was started on the 12th postoperative day when the bacteremia had already subsided. No appreciable effect could be noted from the use of a total of 362,500 units of penicillin.
2	An infection subsequent to a Wagner posterior bone block of the foot was found on the 10th postoperative day, and culture revealed coagulase positive <i>Staph. aureus</i> and secondary invaders. Administration of 20,000 units of penicillin every three hours intramuscularly and daily local application of 250 units per cubic centimeter of isotonic solution of sodium chloride were started on the same day. The total amount of penicillin used was 590,000 units. The temperature did not subside until the wound was drained. The subsequent course did not demonstrate any beneficial effect from the use of penicillin.
3	An infection arose after Hibb's fusion of the lumbosacral area of the spine reenforced by tibial bone grafts. Coagulase positive <i>Staph. aureus</i> was cultured from the blood and the operative wound (spine). The intravenous administration of 150,000 units of penicillin daily and the local application of 250 units per cubic centimeter of sodium chloride solution were started on the 8th postoperative day when the blood was already sterile. A total of 681,000 units was administered without any appreciable effect on the clinical course.
4	An infection incidental to an open reduction of a fracture on the neck of the femur and fixation with a Thompson Z nail was noted on the 10th postoperative day, the wound was opened penicillin was applied locally and an immediate dose of 40,000 units was administered intramuscularly. This was followed by doses of 20,000 units given every 3 hours and daily local applications of 250 units per cubic centimeter of sodium chloride solution. The wound yielded coagulase-positive <i>Staph. aureus</i> and secondary invaders, the <i>Staph. aureus</i> was found to be resistant to 3.0 units of penicillin and was destroyed by 6.0 units while the blood concentration was only 0.312 unit. Sulfa thiazole was therefore given by mouth in addition to the penicillin. The temperature continued to go up to 104 F and chills occurred on the 17th, 19th and 20th postoperative days. The blood culture continued to reveal organisms till the 25th postoperative day. Thereafter the temperature began to drop to more normal levels and on the 29th day the blood culture was sterile. Penicillin to the amount of 3,460,000 units was administered intramuscularly over a period of 23 days in addition to the local application of the drug, 86 Gm of sulfathiazole was administered over a period of 15 of the 23 days and several transfusions were given. Penicillin alone and the reenforcement with sulfathiazole did not seem to have any influence on the course of infection and the patient continued to have a persistent sinus and nonunion. The nail was extruded during the course of the infection.
5	After arthroplasty for ankylosed hip incidental to Marie Strumpell disease and immobilization in a plaster of paris spica for 18 days during which the highest temperature was 100 F, a pronounced rise in temperature developed subsequent to the removal of the spica. Repeated examinations and aspirations of the operative site failed to reveal any infection. On the 27th postoperative day an area of redness was noted, this was probed, and pus was encountered and evacuated. The area was flooded with isotonic solution of sodium chloride containing 250 units of penicillin per cubic centimeter and intramuscular administration of 20,000 units of the drug every 3 hours was started immediately. Neither the temperature nor the discharge was controlled till the wound was opened under general anesthesia and the limb remobilized in a plaster of paris spica. A second exploration, with removal of diseased bone, flooding of the wound with penicillin and closure without drainage in association with the preoperative and postoperative administration of penicillin intramuscularly finally resulted in healing. The primary administration of 1,480,000 units of penicillin at the onset of the infection was totally ineffective.
6	Prior to the performance of an intra-articular arthrodesis of a hip and its fixation with a Thompson Z nail 100,000 units of penicillin was administered in 5 doses. For some unexplained reason the operative wound was not flooded with penicillin, nor was the postoperative intramuscular administration of penicillin carried out. A culture from the operative field was sterile. On the 6th postoperative day the patient was found to have a streptococcal dermatophytosis of one hand. A moderate rise in temperature persisted. The wound was dressed on the 8th day and a slight sanguineous discharge was noted. A culture revealed a coagulase positive <i>Staph. aureus</i> sensitive to 0.078 unit of penicillin and secondary invaders. The discharge persisted and increased. Local and systemic penicillin therapy was started on the 13th postoperative day and a total of 2,600,000 units was administered over a period of 17 days without any influence whatsoever on the infection. After a period of 2 months the wound and sinus were subjected to a thorough debridement flooded with penicillin and closed without drainage in conjunction with the preoperative and postoperative administration of 20,000 units of penicillin intramuscularly every 3 hours. The wound healed in 20 days.
8	On the 6th day after an arthrodesis of a flail knee incidental to polyomyelitis and its fixation with a Townsend Gilliland plate and a plaster of paris cylinder the patient's temperature rose to 102.6 F. The plaster bandage was bivalved and a purulohemorrhagic discharge was encountered. Systemic and local applications of penicillin were started immediately. During the following 4 days, the temperature gradually subsided. A number of sinuses developed and pus was drained. After a period of 40 days all wounds healed. A total of 2,180,000 units of penicillin was administered over a period of 14 days. The effect on the wound is dubious. The infective organism was a coagulase positive <i>Staph. aureus</i> sensitive to 0.01 unit of penicillin.
9	The start of systemic and local applications of penicillin on the 6th day after an operation for a fracture of the neck of the femur and its fixation with a Thompson Z nail in a 70 year old woman suffering from chronic rheumatoid arthritis and pernicious anemia with a fluctuating temperature and local evidence of infection failed to produce a favorable influence on the clinical course. The wound broke down and drained copiously. After a period of 9 days the temperature subsided and the use of penicillin was discontinued. Ten days later the systemic administration of 30,000 units of penicillin was started again. Seven days thereafter the temperature began to increase and metastatic foci developed in the ipsilateral knee and contralateral ankle. Large quantities of penicillin were used without any appreciable effect on the course of the disease.

clinical signs are present to indicate the presence of an infection. In view of this, penicillin therapy if it is to be effective must be started before the evidences of the infection are clinically apparent, that is, at the time of the operative procedure. That this reasoning is correct is indicated by the data presented in tables 1 and 2 on a series of 48 patients subjected to a large variety of operative procedures under varying conditions of preoperative, operative and postoperative trauma without a single gross postoperative infection.

CONCLUSIONS

In view of the foregoing observations it seems reasonable to draw the following conclusions:

1 Penicillin, as the sole agent of therapy, is ineffective in the control of postoperative infections in surgical procedures on bones and joints unless it is administered during the earliest phases of infection, that is, at the time of operation or soon thereafter. This ineffectiveness refers only to the local lesion and not to the systemic lesion (bacteremia), if it should be present.

2 The precautionary antibiotic control of surgical procedures, with primary closure, on bones and joints is an effective method for the prevention of postoperative infections. This consists of the preoperative and postoperative intramuscular administration of adequate doses of penicillin and the flooding of the operative wound at the time of closure without drainage with a penicillin-sodium chloride solution of adequate concentration.

3 The precautionary antibiotic control of surgical procedures, with primary closure without drainage, on bones and joints in persons with quiescent osteomyelitic lesions, regardless of the period of quiescence, is an effective method for the prevention of the flare-up of these infections.

4 The precautionary antibiotic control of surgical procedures, with primary closures without drainage, on bones and joints in the presence of active infection, be it in close proximity or at a distance, is an effective method of obtaining healing of the operative wounds by primary intention. This technic makes possible the shortening of convalescence, the avoidance of secondary operative procedures and in certain instances of amputation the saving of the proximal joint.

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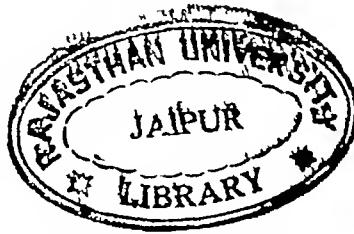
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and to determine the relationship of the deaths to the anesthetic management

The series of 688 intrathoracic operations presented here represents the work of nine surgeons and twenty physician-anesthetists. The greater share of the operations were made by two general surgeons who specialize in thoracic work and three resident surgeons whom they have trained. Some of the sympathectomies were performed by two neurosurgeons. The vagotomies were made by two general surgeons as well as by one of the aforementioned thoracic surgeons. Five faculty physicians and fifteen residents made up the group of twenty physician-anesthetists.

The operations performed are listed in table 1.

Table 2 presents the sex variation in the series of patients. Four hundred and forty-nine, or 68.16 per cent, were males, and 239, or 31.84 per cent, were females. It is noteworthy that the females exceeded the males only in the group who had lobectomy (mostly for bronchiectasis) and in the group who had sympathectomy for malignant hypertension. Eighty-five and four-tenths per cent of those who underwent pneumonectomy were males, as were 83.9 per cent of those who had operations on the esophagus and cardia and 82.4 per cent of those who had vagotomy for peptic ulcer.

The age incidence of these patients appears in table 3. It is of interest that the operations performed on patients below 10 years of age were mainly lobectomies for bronchiectasis and intervention for cardiac lesions. Also there were few operations on the esophagus or cardia in patients under 40 years of age, while 115, or 77.18 per cent, of the patients who had this type of operation were over 50. The majority of patients were above 60 years of age, and 5 were over 80.

The physical state of the patients is revealed in table 4. Only 87, or 12.7 per cent, were in good physical condition, while 230, or 33.4 per cent, were in fair physical condition. Three hundred and seventy-one, or 53.8 per cent, were in poor or serious preoperative condition.

The best risks were in the group having vagotomies for peptic ulcer. From 85 operations in this category there was only 1 death, which occurred early in the series. Regurgitation and aspiration from acute dilatation of the stomach developed after a patient was ambulatory on the second postoperative day, and death ensued on the seventh postoperative day from aspiration pneumonia. This hazard is now eliminated by the judicious aspiration of the stomach postoperatively.

Table 5 presents the incidence, time and cause of death in the total series of 688 operations. Fifty-nine, or 8.5 per cent, of the patients died. The 6 deaths (0.9 per cent) in the operating room were unrelated to anesthesia. They were due to uncontrolled hemorrhage in 3 patients,

tumor thrombus in the heart in 2 and coronary occlusion from the intra-cardiac operation in 1

The greatest number of deaths (15) occurred one to three days postoperatively. It is difficult to differentiate the role of anesthesia, operation and physical status in the deaths from circulatory failure, pulmonary involvement and uremia during this period. The death from tracheal perforation was from a surgical accident. There had been no intrinsic trauma or irritation of the trachea during anesthesia.

Table 6 classifies the deaths as to their apparent cause. There were no deaths due to the anesthesia alone. Of the deaths, 11.86 per cent, or 1.01 per cent in the total series, were due to a combination of anesthesia and operation, while 15.26 per cent (or 1.3 per cent in the total series of operations) were due to the operation *per se*. Twenty-three and seven-tenths per cent (2.03 per cent of the series) were due to the operation and the disease, and the same percentage were due to the disease alone. Of the 14 deaths grouped under "sepsis or late surgical accidents," 5 were due to sepsis, 1 to morphine overdosage, 1 to uremia from sulfathiazole, 2 to uremia from nonanesthetic causes, 4 to separation of sutures and 1 to suicide, making up 23.73 per cent of the total deaths or 2.03 per cent in the series of 688 operations.

COMMENT

Gillespie⁸ found a total of 283 deaths during anesthesia for all types of surgical procedures in 227,546 patients in five teaching hospitals on three continents, making a mortality rate of 0.12 per cent. Waters and Gillespie⁹ reported 47 deaths in the operating room during anesthesia for 44,894 operations of all types, an immediate mortality of 0.104 per cent. Of the 47 deaths, 8, or 17.9 per cent, occurred during intrathoracic operations. Death was due to hemorrhage in 4 patients, hypoxia in 2, obstruction in 1 and circulatory failure in 1. They emphasized the fact that the particular anesthetic agent used is of less importance than its judicious application.

Trent and Gaster¹⁰ reported 38 sudden deaths during anesthesia for 54,128 operations of all types, or 0.702 per thousand. They had 27 so-called anesthetic deaths during general and spinal anesthesias for 39,880 operations of all types, or 0.677 per thousand.

How can deaths during or following intrathoracic surgery be minimized or avoided?

⁸ Gillespie, N. A. Death During Anaesthesia, *Brit. J. Anaesth.* **19**: 1-16 (Jan.) 1944

⁹ Waters, R. N., and Gillespie, N. A. Deaths in the Operating Room, *Anesthesiology* **5**: 113-128 (March) 1944

¹⁰ Trent, J. C., and Gaster, E. Anesthetic Deaths in 54,128 Consecutive Cases, *Ann. Surg.* **119**: 954-958 (June) 1944

TABLE 5.—Cause and Time of Death

Operation	Number of Cases	Deaths Number	Deaths Per Cent	After Operation				Two Months	Three Months
				In Operating Room	1 to 3 Days	4 to 7 Days	7 to 14 Days		
Pneumonectomy	48	15	31.2	2 from hemorrhage	1 from pulmonary edema. 2 from pulmonary emboli	1 from circulatory failure	3 from circulatory failure, 1 from carcinoma of the lung, 1 from bronchial pneumonia, 1 from a cerebral accident	1 from sepsis, 1 from separation of sutures	1 from sepsis,
Bilobectomy and partial pneumonectomy	37	1	2.7					1 from bronchial pneumonia	
Lobectomy	79	0	7.5	1 from tumor thrombus in heart				1 from pulmonary embolism	
Miscellaneous exploratory thoracotomy	44	3	6.8	1 from tumor thrombus in heart		1 from cardiac failure			
Heart and great vessels	33	2	6.0			1 from coronary occlusion		1 from the disease (fibrosis of pleura and peritonitis)	
Mediastinum	37	1	2.7				1 from hemorrhage		

Fibroplastic tracheitis	149	22	154	1 from trachea perforation 1 from pulmonary edema, 1 from edema, 1 from circulatory failure, 2 from sepsis, 1 from other respiratory causes, 1 from bronchial pneumonia 1 from sepsis, 2 from uremia	2 from circulatory failure, 1 from carcinoma, 2 from separation of sutures, 2 from wound sepsis, 1 from pulmonary embolism, 1 from postoperative aspiration pneumonia	1 from carcinoma with pleural effusion 2 from coronary occlusion, 1 from wound infection	1 from lobar pneumonia with empyema	1 from wound separation with empyema
Massive resection of the chest wall	16	2	133	1 from circulatory failure	1 from morphine overdosage			
Sympathectomy	109	3	27	1 from cerebral accident		1 from circulatory failure	1 from uremia	
Vagotomy	80	1	11		1 from aspiration pneumonia (regurgitation after being ambulatory)			1 from suicide
Extrapleural pneumonectomy or plombage	38	2	52			1 from pulmonary hemorrhage and tuberculosis		

Preoperative Preparation—The dehydrated and undernourished patients should receive adequate fluids parenterally administered and plasma and blood transfusions in order to get the fluid and electrolyte balance as well as the plasma protein level as near normal as possible. If esophageal obstruction is not too severe, they should receive a high caloric liquid diet to improve their general condition.

Vital capacity, as well as plasma protein levels and hematocrit readings, must be determined before the operation.

Fluid or secretions must be removed from the esophagus, stomach or respiratory tract before anesthesia. With gastric or esophageal lesions this is easily managed by the use of an aspiration catheter. Pulmonary secretions should be removed as well as possible preoperatively by bronchoscopy and the frequent use of dependent drainage, particularly just before the patient comes to the operating room.

TABLE 6.—*Anesthesia, Operation and Disease as Causes of Death in Intrathoracic Operative Procedures*

Cause of Death	Number	Percentage of 69 Deaths	Percentage of 688 Operations
Residual	0	0	0
Operation	9	13.26	1.31
Operation and disease	15	25.42	2.18
In the lab and operation	7	11.86	1.02
late or late surgical accidents	14	23.73	2.03
Total	69	23.73	2.03
Total deaths	69		8.57

Premedication should be adequate enough to dispel apprehension, relieve pain and yet not to make sputum more tenacious. Overdose with respiratory depression, must be avoided. Most of our patients received premedication one to one and one-half hours before the start of anesthesia. Morphine in dosages of 0.0075 to 0.015 Gm combined with calcium pentobarbital, 0.09 to 0.27 Gm by rectum in 30 to 50 cc of water or pentobarbital sodium, 0.12 to 0.24 Gm intramuscularly were the drugs most frequently employed.

Anesthetic Management—Early in the twentieth century Von Mikulicz,¹¹ Sauerbruch,¹² Meltzer and Auer,¹³ and Elsberg¹⁴ worked

11 Von Mikulicz, cited by Killian, H. Scope and Utility of Differential Diagnosis in Thoracic Surgery, Anesth & Analg 17:154-162 (May-June) 1938.

12 Sauerbruch E F. Present Status of Surgery of the Thorax, J A M A. 51:808-815 (Sept. 5) 1908.

13 Meltzer, S J, and Auer, J. Continuous Respiration Without Respiratory Movements J Exper Med 11:622, 1909.

14 Elsberg C A. The Value of Continuous Intratracheal Insufflation of Air in Thoracic Surgery, M Rec. 77:493, 1910.

on mechanical methods of solving anesthetic management in intrathoracic surgery. At the present time four methods of anesthetic management are employed in this type of surgery: (1) anesthesia by the endotracheal technic,¹⁵ (2) anesthesia by the face mask technic with positive pressure,¹⁶ (3) high spinal anesthesia¹⁷ and (4) local anesthesia.¹⁸

The maintenance of the anesthetic state is but a small part of the problem in intrathoracic procedures. Adequate pulmonary ventilation at all times is of most importance and is the responsibility of the anesthetist. Undue alteration in the cardiorespiratory mechanism must be prevented.

The two most important problems for the anesthetist are the prevention of anoxia and the removal of foreign material from the trachea and bronchi.

Good postural drainage should be provided throughout anesthesia. Often in severe cases of increased pulmonary secretion the air passages may become obstructed if good postural drainage and adequate oral suction are not employed during induction of general anesthesia and before the plane of narcosis has been reached. This difficulty arises before the plane of narcosis has reached a sufficient depth to permit the introduction of an endotracheal catheter, if that method is employed. The difficulties that may be encountered by the anesthetist with endotracheal anesthesia in intrathoracic surgery have been thoroughly discussed by Maier.¹⁹

A longer induction period is required if the endotracheal technic is to be employed, which prolongs the total period of anesthesia. Intubation, if employed, must be carefully and expertly performed under deep anesthesia, without local injury and without producing even momentary anoxia, as patients undergoing thoracic operations are less able to tolerate hypoxia or additional manipulative procedures than the average surgical patient. We have not considered it imperative to introduce an endotracheal catheter if a clear airway is evident during induction, and

15 Dunlap, J. G. Anesthetic Practices in Thoracic Surgery, *Anesth & Analg* 18:301-311 (Nov-Dec) 1939.

16 Phillips, F., Livingstone, H. M., and Adams, W. E. A Clinical Consideration of Anesthesia in Intrathoracic Operations, *Anesth & Analg* 20:78-87 (March-April) 1941.

17 Magill, I. W. Anesthesia in Thoracic Surgery, with Special Reference to Lobectomy, *Proc Roy Soc Med (Sect Anesth)* 29:7-16 (April) 1936.

18 Overolt, R. H., Wilson, N. J., and Langer, I. Further Experience in Pulmonary Resection in the Treatment of Pulmonary Tuberculosis, read at the meeting of the American Association for Thoracic Surgery, Detroit, May 31, 1946.

19 Maier, H. C. Responsibility of the Anesthetist in Reducing the Operative Complications of Thoracic Surgery, *Anesthesiology* 5:11-21 (Jan) 1944.

we have experienced no difficulty in producing adequate positive pressure by the use of an oral airway, a tight-fitting face mask and an anesthesia machine which gives positive pressure. Suction of the oral and pharyngeal areas, aided by a position of the patient favoring drainage during the operation, has seemed satisfactory. The majority of the patients have immediate postoperative bronchoscopic aspiration while still in the operating room. Oxygen is administered during bronchoscopy.

The lateral recumbent position for intrathoracic procedures causes more respiratory difficulty than the supine position, hence it is a wise practice to induce anesthesia with the patient in the latter position and, after good surgical anesthesia and a patent airway has been established, then to place and secure the patient in a proper position which interferes least with the pulmonary ventilation.

Cooperation between the anesthetist and the surgeon is essential. The surgeon must always be kept informed of the actual condition of the patient, for he may be able to assist in overcoming any difficulties or to modify his surgical management to prevent a disaster.

Increased respiratory effort on the part of the patient indicates inadequate pulmonary ventilation. This may be due to obstruction in the air passages or to inadequate inhalation pressure of oxygen. The detrimental effects of anoxia may lead to cardiac failure as well as to damage to the central nervous system. It is questionable if controlled respiration is a safe procedure, and most surgeons find it unnecessary.

It has been found that when the inhalation anesthetic agent, combined with an adequate amount of oxygen, is administered with sufficient inhalation pressure, the blood arterial oxygen can be kept at a satisfactory level.²⁰ Oxygen administered with adequate inhalation pressure is most important. The amount of distention or deflation of the lungs should be controlled by regulating the exhalation pressure rather than by decreasing the inhalation pressure if asphyxia is to be avoided. A normal cardiorespiratory mechanism can be maintained through proper control of inhalation pressure and the judicious use of analeptics or other drugs when indicated. It is also assisted by the prompt replacement of any fluid or blood loss.

Intrathoracic operations should not be started without a cannula being in place intravenously and a blood transfusion started or immediately available. White and Buxton²¹ found an average loss of blood of 1,607.5 cc in 10 lobectomies and an average loss of 1,458 cc in 6 pneum-

²⁰ Thornton, T. F., Jr., Martin, R. C., Livingstone, H. M., and Adams, W. E. The Effect of Variations of Intratracheal Pressure and Anesthetic Mixtures on the Arterial Blood Oxygen, *Anesthesiology* 6:498-504 (Sept.) 1945.

²¹ White, M. L., Jr., and Buxton, R. W. Blood Loss in Thoracic Operations, *J. Thoracic Surg.* 12:198-202 (Dec.) 1942.

monectomies. The investigation of Thornton, Adams and Schafer²² substantiated these findings. It is necessary to replace promptly all blood lost during the surgical procedure if shock is to be avoided. In addition, it has been found that after pneumonectomy the pleural fluid which accumulates in the remaining space contains 4 to 5 Gm of protein per hundred cubic centimeters. Since this space usually has a capacity of between 700 and 1,000 cc, the amount of protein thus removed from the circulating blood and the body tissues is considerable. Hypoproteinemia, with its resulting ill effects, can be avoided by filling this pleural space with plasma at the time of the operation, as advocated by Adams and his associates,²³ in addition to administering an adequate amount of blood or serum intravenously.

Anesthetic drugs having the least tissue toxicity and a minimum of depression to the respiratory mechanism should be employed, and an effort should be made to have the patient awake as soon as possible after the procedure. We most frequently employ ethylene-oxygen induction and add ether with an increased amount of oxygen during maintenance. The snug-fitting face mask with a positive inhalation pressure of 4 to 8 mm of mercury was employed throughout except in a few vagotomies, in which for teaching purposes cyclopropane, oxygen and ether were used endotracheally.

Just before the chest is closed the anesthetist should gently reinflate the lung with moderately increased positive pressure, so as to reexpand, under direct vision, any atelectatic areas. Overdistention and tension on suture lines must be avoided. At the close of the operation the residual air in the pleural cavity is aspirated by the use of a pneumothorax apparatus until the pressures are within normal limits (8 to 16 cm of water).

Routine bronchoscopic aspiration of mucopus and blood from the tracheobronchial tree is indicated in the operating room before the patient recovers consciousness.

Postoperative Management.—Oxygen therapy should be instituted as soon as the patient returns from the operating room. Nasopharyngeal insufflation of 10 to 12 liters per minute of humidified oxygen is a simple and efficient method of management. A patent airway must be maintained. Bedside suction is extremely necessary, and mucus and other secretions in the upper air passages must be removed promptly. The endotracheal aspiration technic of Haight²⁴ is a valuable procedure in

22 Thornton, T F, Jr., Adams, W E, and Schafer P W. Hypoproteinemia in Thoracic Surgery, Surg, Gynec & Obst. 79:368-373 (Oct.) 1944.

23 Adams, W E, Thornton, T F, Jr., and Carlton, L M Jr. The Use of Blood Plasma for Filling the Pleural Space Following Total Pneumonectomy, Ann Surg 122:905-916 (Dec) 1945.

24 Haight, C. Intratracheal Suction in the Management of Postoperative Pulmonary Complications, Surg 6:445-449 (Sept) 1939.

some patients When this method does not suffice for the removal of tenacious bronchial secretions, bronchoscopy should be employed

During the first twenty-four hours after surgical intervention, an apparatus for the administration of oxygen with positive pressure should be kept readily available It is rarely needed but is a valuable safeguard in case of emergency

The surgeon should use continuous suction drainage applied to a stab wound drain of the pleural cavity except after pneumonectomy This prevents an accumulation of exudate and maintains the lungs in complete expansion Usually a double Wangensteen apparatus is employed, which maintains a siphonage of 25 to 30 cc of water

Adequate water and mineral balance must be maintained through the use of intravenously and subcutaneously administered fluids as long as necessary After resection of the esophagus, nothing by mouth is advisable for at least four to five days Transfusions of blood and plasma should be repeated whenever indicated to prevent postoperative shock, anemia and hypoproteinemia and to hasten convalescence The hematocrit reading has been a much better index than the red blood cell count or the hemoglobin value for the determination of the true state of the oxygen-transporting medium²⁵

SUMMARY

A series of 688 intrathoracic operations are presented, and the death of 59, or 8.57 per cent, of the patients is discussed An attempt has been made to determine the relationship of the deaths to the anesthetic and surgical management The principles that should be observed in the management of patients undergoing intrathoracic procedures are presented in an effort to reduce the incidence of fatalities from this type of surgical treatment

In comparison with the reported death rates in the operating room for all types of operations, the incidence of deaths from operations of the magnitude of intrathoracic procedures is not high in view of the patients' preoperative physical status

25 Adams, W E, Thornton, T F, Carlson, A J, and Livingston, H M
Anoxia and Anesthesia in Intrathoracic Operations, *Surgery* 13: 859-879 (June)
1943

ASCORBIC ACID, THIAMINE, RIBOFLAVIN AND NICOTINIC ACID IN RELATION TO ACUTE BURNS IN MAN

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ALTERATIONS in the metabolism of proteins, carbohydrates and electrolytes following burns have been extensively studied in the past few years. In contrast, few investigations of possible changes in vitamin metabolism following burns have been made. Uzbekov,¹ Clark and Rossiter² and Harkins³ have reported decreased ascorbic acid content of the adrenal cortex in burned guinea pigs and rabbits, while Lam⁴ has reported a decrease in the plasma ascorbic acid concentration in

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From the Thorndike Memorial Laboratory, Second and Fourth Medical Services (Harvard) and the Burns Assignment of the Surgical Services, Boston City Hospital, the Department of Medicine and Surgery, Harvard Medical School, and the Fatigue Laboratory of the Harvard Business School.

1 Uzbekov, G A Problem of Avitaminoses Effect of Burns on Metabolism of Vitamin C, Klin med 15 237-240, 1937

2 Clark, L J, and Rossiter, R J Carbohydrate Metabolism After Burning, Quart J Exper Physiol 32 279-300, 1944

3 Harkins, H N Present Status of the Problem of Thermal Burns, Physiol Rev 25 531-572, 1945

4 Lam, C R Chemical Pathology of Burns Collective Review, Surg., Gynec & Obst. 72 390-400, 1941

patients with extreme burns Andreae, Schenker and Browne⁵ found that patients with burns or fractures characteristically showed a pronounced retention of riboflavin during the first three to five days after injury This was followed by a period of similar duration in which there occurred an increased loss of riboflavin in the urine About ten days after injury the riboflavin balance returned to normal They suggested that the riboflavin retained during the first period was stored in some way and subsequently released Later, during the convalescent period, both nitrogen and riboflavin were retained, 0.3 mg of riboflavin being retained for each gram of nitrogen Andreae and Browne,⁶ in a later report, confirmed these observations, and in addition reported a high retention of ascorbic acid in similar patients in the early days after injury, which, in contradistinction to the retention of riboflavin, was not followed by a period of increased loss of ascorbic acid This, they expressed the belief, could not be attributed to preexisting deficiency, faulty absorption, impaired excretion, retention in the tissues or in the edema fluid or excretion in the form of dehydroascorbic acid

The present study is concerned with the alteration in the plasma concentration of ascorbic acid and in the urinary excretion of ascorbic acid, thiamine, riboflavin and N-methylnicotinamide in patients with burns admitted to the Boston City Hospital during 1944-1945

METHODS

The patients studied were cared for by members of the Burns Assignment of the Surgical Services of the Boston City Hospital The dietary calculations were made by a research dietitian All hematologic and routine chemical determinations were made by the methods previously published from the Thorndike Memorial Laboratory⁷ Determinations of plasma ascorbic acid were made in the Thorndike Memorial Laboratory by the method of Mindlin and Butler⁸ The determinations of vitamin output were made in the Harvard Fatigue Laboratory, the field methods⁹ developed there being used Both fasting and hourly excretion rates and the excretions after the injection of test doses were determined Low fasting hourly excretion rates of ascorbic acid, thiamine, riboflavin and N-methylnicotinamide

5 Andreae, W A , Schenker, V , and Browne, J S L . Riboflavin Metabolism After Trauma and During Convalescence in Man, Federation Proc 5 3, 1946

6 Andreae, W A , and Browne, J S L , in Proceedings of the Eighth Meeting of the Associate Committee on Army Medical Research, National Research Council of Canada, Ottawa, 1946

7 Levenson, S M , Davidson, C S , Lund, C C , and Taylor, F H L . The Nutrition of Patients with Thermal Burns, Surg , Gynec & Obst 80 449-469, 1945

8 Mindlin, R L , and Butler, A M . Determination of Ascorbic Acid in Plasma, Macromethod and Micromethod, J Biol Chem 122 673-686, 1938

9 Johnson, R E , Sargent, F , Robinson, P F , and Consolazio, F C . Assessment of Nutrition and Metabolic Conditions in the Field, War Med. 7 227-233 (April) 1945

together with low excretions of these substances after injection of test doses have been considered indicative of tissue unsaturation⁹. The fasting hourly excretion rates were usually determined three times a week on alternate days. For presentation in some of the accompanying charts and tables and in part of the text, the figures from these determinations and also from the plasma ascorbic acid determinations have been averaged and the weekly average listed. The average fasting hourly excretion of the four vitamins under consideration in normal adult males on a normal diet⁹ is represented on the charts by dotted lines at the appropriate levels.

Vitamin supplements were given orally in the form of ascorbic acid tablets and "multicebrin" capsules. These contain the following in each capsule thiamine hydrochloride, 30 mg, riboflavin, 30 mg, pyridoxine hydrochloride, 1.5 mg, pantothenic acid, 50 mg, nicotinamide, 25 mg, ascorbic acid, 75 mg, distilled natural tocopherols, 10 mg, vitamin A, 5,000 U.S.P. units, and vitamin D, 1,000 U.S.P. units. Vitamins were given intravenously in the form of single or multiple vitamin preparations.

Saturation tests of vitamins were made in the following manner. After a fasting specimen of blood and a fasting hourly specimen of urine were taken, the test doses were given intravenously. Specimens of blood and of urine were then collected at intervals of one-half, one, two, three and four hours. Two different test doses were used. One, named a "high test" dose, contained 1 Gm of ascorbic acid, 20 mg of thiamine hydrochloride, 12 mg of riboflavin and 200 mg of nicotinamide. The other, the "low test" dose, contained 250 mg of ascorbic acid, 5 mg of thiamine-hydrochloride, 3 mg of riboflavin and 50 mg of nicotinamide. The field methods of the Harvard Fatigue Laboratory have been used to study fasting hourly excretions and excretions after "low" saturation tests on many thousands of soldiers in all parts of the world⁹. Both "high" and "low" saturation tests have been made on many normal subjects and scurvy patients at the Boston City Hospital, and the results of these studies will be published shortly¹⁰.

The percentage of body surface burned was estimated by the method of Lund and Browder¹¹. The depth of burn was classified according to the method of Converse and Robb-Smith¹². In some cases the depth of burn cannot be estimated accurately on the patient's entry to the hospital and for some time thereafter. For patients who died before an accurate classification of the depth could be made, the area of deep burn was estimated as fairly as possible. Dressings in most instances were dry sterile pressure dressings¹³ applied usually without anesthesia. The dressings were changed at one to two week intervals. Grafting was done by the Padgett dermatome technic under cyclopropane anesthesia.

The patients have been divided according to age, children and adults being considered separately. This was done for the following reasons (1) children are actively growing, (2) the children's wards were better staffed with nurses and (3)

10 Lewis J., Davidson, C. S., Adams, M. A., Robinson, P., Paige, R. W., MacDonald, A. H., Taylor, F. H. L., and Johnson, R. E. Unpublished data.

11 Lund, C. C., and Browder, N. C. Estimation of Areas of Burn, Surg., Gynec & Obst. 79: 352-358, 1944.

12 Converse, J. M., and Robb-Smith, A. H. T. The Healing of Surface Cutaneous Wounds Its Analog with the Healing of Superficial Burns, Ann. Surg. 120: 873-875, 1944.

13 Levenson, S. M. and Lund, C. C. Dermatome Skin Grafts for Burns in Patients Prepared with Dry Dressings and With and Without Penicillin, New England J. Med. 233: 607-612, 1945.

the food offered to the children was by and large 'better' than that offered to the adults and usually contained appreciably more vitamins. Each group has in turn been divided into those with 'minor' and those with 'major' burns, the latter group being comprised of patients with more than 15 per cent total burn or more than 9 per cent deep burn.

RESULTS

The cases studied are listed in the tables.

Children—Minor Burns. Four children (cases 1 to 4) with minor burns were studied. All were in excellent nutritional status on entry to the hospital and none had any complications before or after the burns. The fasting concentrations of plasma vitamin C and the fasting hourly excretion rates of the various vitamins are listed in table 2. In all instances these were within the expected 'normal' range. Saturation tests were performed on 1 patient (case 4) when he was essentially healed, the "high test" dose being injected. The four hour excretions and the plasma vitamin C levels at this time were normal.

TABLE 1—Classification of Children with Burns

Case	Age	Sex	Percentage of Body Surface Burned		Past His- tory	Nutri- tional Status on Entry	Shock *	Ane- mia *	Local Hypo- protein- emia †	Food on Dis- (Late)	Nutri- tional Status	Result	
			Total	Deep									
1	14	F	3	0	†	Good	0	0	0	1	Good	Good	Living
2	8	M	3	1	†	Good	0	0	0	1	Good	Good	Living
3	4	F	6	3	†	Good	0	0	0	1	Good	Good	Living
4	10	M	10	6	†	Good	0	0	0	1	Good	Good	Living
5	5	M	80	25	†	Good	+	+	+	8	Fair	Poor	Dead
6	6	F	65	60	†	Good	+	0	0	—	Good	Good	Dead

* + signifies present and 0 absent.

† 1 indicates slight, 2 moderate and 3 severe.

‡ Noncontributory.

Severe Burns. Two children (cases 5 and 6) with severe burns were studied. The patient in case 5 was a 5 year old boy, previously healthy, with extensive deep burns. Despite an intake of over 200 Gm of protein and 4,000 calories daily, it was impossible to keep him in good nutritional status. He gradually lost weight, granulations were absent and local exudation and fever were pronounced. He received large daily supplements of the various vitamins as listed in table 2. The fasting plasma vitamin C level and hourly excretion rates of the vitamins and the response to injection of "high test" doses were determined only in the seventh and the ninth week and were within the expected range.

The patient in case 6 was a 6 year old girl, previously healthy, with an extensive deep burn who was in severe shock for about one hour after her entry to the hospital and again twelve hours later. Fasting hourly excretion rates of ascorbic acid, thiamine, riboflavin and N-methyl-

TABLE 2.—Fasting Hourly Excretion Rates and Plasma Vitamin C Concentrations in Children with Burns

nicotinamide at the twenty-second hour after injury, before any vitamin supplements were given, were normal. She died on the third day before any further tests were made.

Adults—Minor Burns. Eleven adults (cases 7 to 17) with minor burns were studied. Little change from normal in the excretion of thiamine, riboflavin, N-methylnicotinamide and ascorbic acid or in the plasma concentration of ascorbic acid was noted except in patients with

TABLE 3.—Classification of Adults with Burns

Case	Age, Sex	Percentage of Body Surface Burned		Past History*	Nutri- tional Status on Entry	Shock†	An- emia ‡	Hypo- protein- emia ‡ (Late)	Local Exuda-	Food Intake	Nutri- tional Status on Dis- charge	Result
		Total	Deep									
7	34 M	6	0	0	Good	0	0	0	1	Poor	Fair	Living
8	31 M	8	0	0	Good	0	0	0	1	Poor, then good	Good	Living
9	57 F	3	1	0	Good	0	0	0	1	Good	Good	Living
10	35 M	3	1	0	Good	0	0	0	1	Good	Good	Living
11	52 F	3	1	0	Good	0	0	0	1	Fair	Good	Living
12	28 F	3	1	0	Good	0	0	0	1	Good	Good	Living
13	46 M	8	1	0	Good	0	+	0	1	Good	Good	Living
14	26 F	4	1	0	Fair	0	+	0	2	Fair	Fair	Living
15	24 F	5	2	0	Good	0	+	0	2	Good	Good	Living
16	54 M	6	2	Chronic osteomyelitis	Good	0	0	0	2	Fair	Fair	Living
17	60 M	0	4	Alcoholism, chronic colitis and diarrhea	Poor	0	+	0	2	Good	Good	Living
8	27 F	18	1	0	Good	0	0	0	1	Good	Good	Living
19	12 F	20	2	0	Good	+	0	0	2	Good	Good	Living
20	27 M	40	30	Alcoholism	Fair	0	+	+	3	Good	Fair	Dead
21	33 M	40	80	0	Good	0	0	+	3	Good	Good	Dead

* 0 signifies noncontributory.

† + means present and 0 absent.

‡ 1 indicates slight, 2 moderate and 3 severe.

some complicating factor such as preexisting deficiency, low food intake, high fever, alcoholism or serious infection (table 4). The courses of patients with such complications are given in detail.

CASE 8.—L. A., a 31 year old white man with a noncontributory past history, was admitted to the hospital shortly after receiving dermal burns of his face, scalp, neck and right forearm and hand. The total area of the body surface burned was 9 per cent. His face and neck were treated with frequently changed petroleum gauze strips that were not bandaged. The forearm and hand were treated with a

dry sterile pressure dressing. Because of pain and swelling of the mouth and face, he took no oral feeding during the first week and only small amounts in the second week. He was given feeding intravenously that included 100 Gm of amigen daily during this time, but he lost 8 pounds (3.6 Kg) in weight. His temperature ranged as high as 104 F and as low as 100 F for one week but became normal thereafter. There was no evidence of any spreading infection at any time. At the time of the first dressing of the arm, at fourteen days, only small scattered areas on the forearm and face were unhealed. When discharged at the end of the fourth week, his burns were healed and he had regained his lost weight. The data on the vitamins are shown in charts 1 and 2.

During the first six days the patient received no vitamin supplements and little oral food. The fasting hourly excretion rates of ascorbic acid, thiamine, riboflavin and nicotinamide were below the average values found in healthy persons on a normal diet. The plasma vitamin C concentration, which was 0.2 mg per hundred cubic centimeters on the second day, fell to zero on the fourth day. Thereafter it rose to a level of 0.6 mg on the sixth day. During the second and third weeks he received a supplement of 150 mg of ascorbic acid daily in the form of orange juice. The hourly excretion rate rose to an average of 4.2 mg per hour, and the fasting plasma vitamin C level rose to 0.7 mg per hundred cubic centimeters. A saturation test with 1 Gm of vitamin C was performed on the ninth day. The four hour excretion was 263 mg, which is below the amount excreted by normal healthy persons on a normal diet. The plasma C level half an hour after the injection of the test dose was also low. We believe that the low excretions of vitamins and the low response to the ascorbic acid saturation test were due to a combination of starvation and burns.

During the third and fourth weeks the supplement of ascorbic acid was increased to 450 mg daily given orally, and oral supplements of thiamine, riboflavin and nicotinamide were given in amounts of 9, 6 and 60 mg respectively. The fasting hourly excretion rate of all the vitamins rose from the previous low levels—the ascorbic acid to about 15 mg per hour the thiamine to 20 micrograms per hour, the riboflavin to 75 micrograms per hour and the N-methylnicotinamide to 0.5 mg per hour.

Case No. Supplemental Daily Intake, Mg

	Gamma-4 - Lasting	Hourly Intake	Rate of Thiamine in Adults
	Weeks	Weeks	Weeks
1	4	5	6
2	5	6	7
3	6	7	8
4	7	8	9
5	8	9	10
6	9	10	11
7	10	11	12
8	11	12	13
9	12	13	14
10	13	14	15
11	14	15	16
12	15	16	17
13	16	17	18
14	17	18	19
15	18	19	20
16	19	20	21
17	20	21	22
18	21	22	23
19	22	23	24
20	23	24	25
21	24	25	26

Riboflavin (Output in Micrograms)

	Gamma-4 - Lasting	Hourly Intake	Rate of Thiamine in Adults
	Weeks	Weeks	Weeks
1	1	2	3
2	2	3	4
3	3	4	5
4	4	5	6
5	5	6	7
6	6	7	8
7	7	8	9
8	8	9	10
9	9	10	11
10	10	11	12
11	11	12	13
12	12	13	14
13	13	14	15
14	14	15	16
15	15	16	17
16	16	17	18
17	17	18	19
18	18	19	20
19	19	20	21
20	20	21	22
21	21	22	23

B Thiamine (Output in Micrograms)

	Gamma-4 - Lasting	Hourly Intake	Rate of Thiamine in Adults
	Weeks	Weeks	Weeks
1	0	40	40
2	1	40	40
3	2	40	40
4	3	40	40
5	4	40	40
6	5	40	40
7	6	40	40
8	7	40	40
9	8	40	40
10	9	40	40
11	10	40	40
12	11	40	40
13	12	40	40
14	13	40	40
15	14	40	40
16	15	40	40
17	16	40	40
18	17	40	40
19	18	40	40
20	19	40	40
21	20	40	40

Thiamine (Output in Micrograms)

31

34

130

63

36

50

225

38

125

110

B-Criteria									
Gamma Output (in cm)									
1	2	3	4	5	6	7	8	9	10
1	11	12	13	14	15	16	17	18	19
2	6	5	4	3	2	1	0	-1	-2
3	10	11	12	13	14	15	16	17	18
4	11	10	9	8	7	6	5	4	3
5	12	13	14	15	16	17	18	19	20
6	1	2	3	4	5	6	7	8	9
7	10	11	12	13	14	15	16	17	18
8	11	10	9	8	7	6	5	4	3
9	12	13	14	15	16	17	18	19	20
10	1	2	3	4	5	6	7	8	9
11	2	1	0	-1	-2	-3	-4	-5	-6
12	3	2	1	0	-1	-2	-3	-4	-5
13	4	3	2	1	0	-1	-2	-3	-4
14	5	4	3	2	1	0	-1	-2	-3
15	6	5	4	3	2	1	0	-1	-2
16	7	6	5	4	3	2	1	0	-1
17	8	7	6	5	4	3	2	1	0
18	9	8	7	6	5	4	3	2	1
19	10	11	12	13	14	15	16	17	18
20	11	12	13	14	15	16	17	18	19

C \\ *Wishful thinking (Output in Morse)*

Patient	Supplemental Daily Intake	Weeks												D Ascorbic Acid (Output in Milligrams)
		1	2	3	4	5	6	7	8	9	10	11	12	
7	0	3.2	0.0											
8	250	1.0	4.2	10.5	2.5	0.5	0.8	1.5						
9	0	0												
10	0													
11	0													
12	0													
	1,000													1.8
13	250													
14	1,000													
15	0													
	1,000													
16	0													
	1,000													
17	0													
18	0													
19	0													
	250													
20	0													
	1,000													
21	600	4.2												
	566													

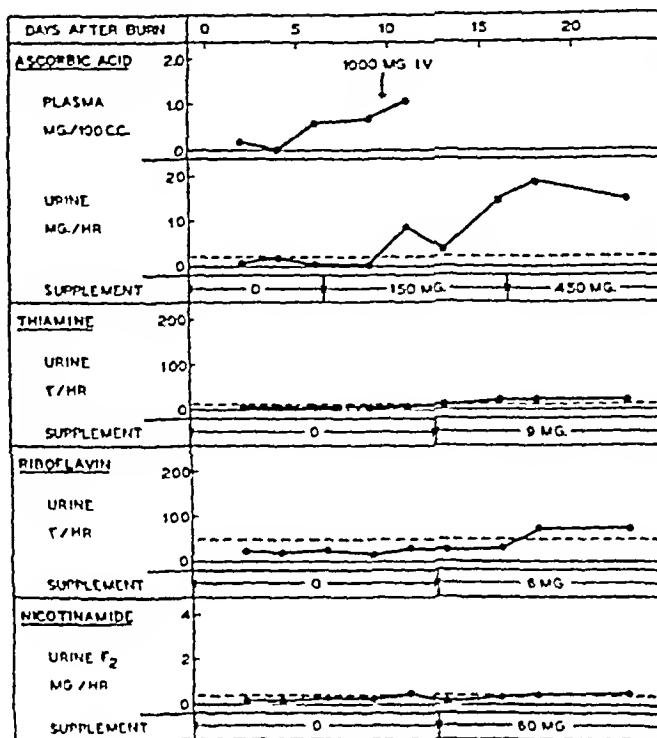


Fig 1 (case 8).—Plasma ascorbic acid concentration and fasting hourly excretion rates of ascorbic acid, thiamine, riboflavin and N-methyl nicotinamide in an adult with a minor burn.

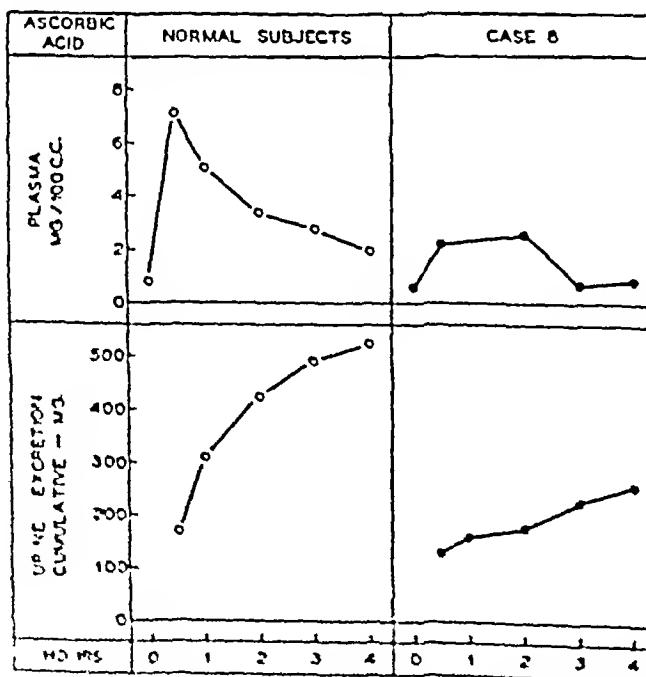


TABLE 5—"Low" Saturation Tests of Vitamin Excretion in Four Hours in a Patient Studied (Case 15)*

Day	Ascorbic Acid, Mg	Thiamine, Mg	Riboflavin, Mg	N Methyl Nicotinamide, Mg
47th	181	24	04	130
52d	228	17	04	63

* The test doses given (intravenously) were ascorbic acid, 250 mg, thiamine, 5 mg, riboflavin, 3 mg, and nicotinamide, 50 mg.

it was normal, at which level it remained thereafter. The patient's appetite was fairly good, but she continued to take little citrus fruits. The plasma protein concentration varied between 5.5 and 6.3 Gm per hundred cubic centimeters. There was slight loss of weight. Skin grafting was first done in the seventh week, with only about a 20 per cent take. She was then given 1 Gm of vitamin C a day, and a second and a third skin grafting were done in the tenth and eleventh weeks, with a 100 per cent take each time. Her weight at this time was 102 pounds (46 Kg), her weight before entry to the hospital having been 107 pounds (48.5 Kg). Her further course was benign, and she was discharged in the thirteenth week. The data on the vitamins are given in charts 3 and 4 and in table 5.

No supplements of thiamine, riboflavin or nicotinamide were given throughout the course in the hospital. The fasting hourly excretion rates of these vitamins were normal as were the four hour excretions after the injection of test doses in the seventh and twelfth weeks. In contrast, during the first seven weeks, when no supplement of ascorbic acid was given, although the fasting hourly excretion rates of ascorbic acid were low normal the fasting plasma vitamin C concentrations were extremely low. The four hour excretion after the injection of 250 mg was exceedingly low on the forty-seventh day, only 13 mg being excreted. This is approximately the amount excreted after a similar injection in patients with scurvy.¹¹ The plasma levels of ascorbic acid after the injection of one test dose were also low, being similar to the levels seen in patients with scurvy. We believe that the failure of the first skin graft on this patient was due in part to a deficiency of ascorbic acid of such severity that formation of connective tissue and capillaries was impaired.¹⁴

From the eighth week the patient was given a supplement of 1 Gm of ascorbic acid daily. The fasting plasma ascorbic acid level had risen to 1.3 mg per hundred cubic centimeters four weeks later. The fasting hourly excretion rates in the eleventh and twelfth weeks were extremely high, being 16 and 23 mg respectively. The four hour excretion in the twelfth week after injection of 250 mg was 228 mg.

¹⁴ Bartlett, M. K., Jones, C. M., and Ryan, A. E. Vitamin C Studies on Surgical Patients, Ann. Surg. 111: 1-26, 1940.

as compared with 13 mg excreted in the seventh week. The plasma ascorbic acid levels at this time were also normal.

CASE 16—M. H., a 54 year old white man with a past history of chronic osteomyelitis of the femur, was admitted to the hospital shortly after receiving

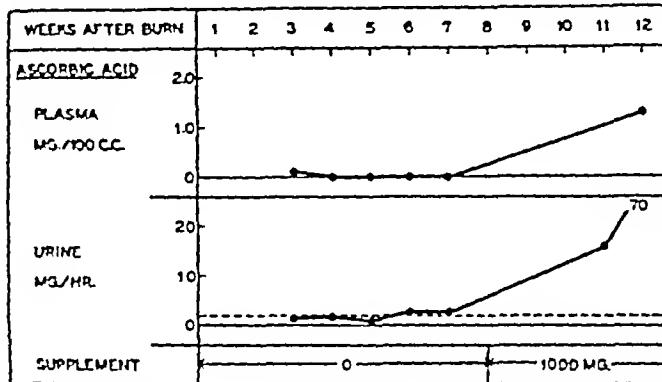


Fig. 3 (case 15).—Plasma ascorbic acid concentration and fasting hourly excretion rates in an adult with a minor deep burn, whose normal intake of ascorbic acid was extremely low.

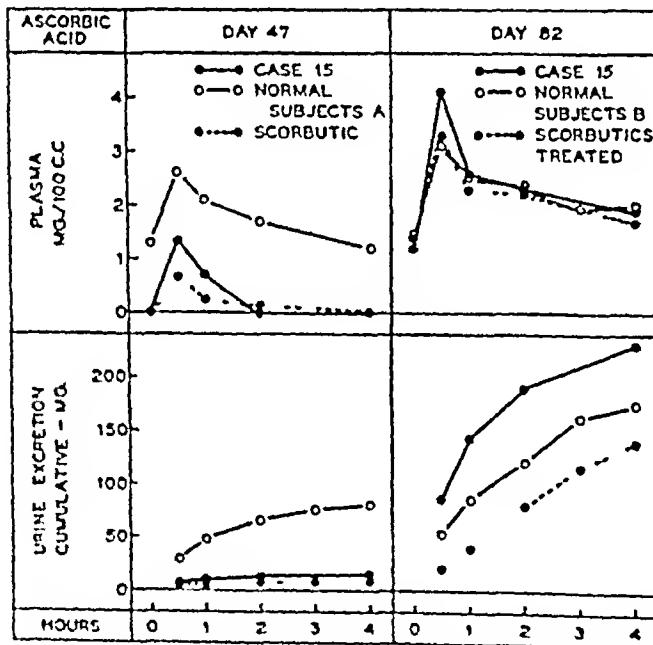


Fig. 4 (case 15).—Ascorbic acid saturation tests in a patient with a minor burn (1) whose normal intake of ascorbic acid was low. The test dose was 500 mg given orally.

During the first two months his appetite was poor, principally because he did not like the food, and his food intake was low. During this time he lost 45 pounds (20 Kg) in weight. Thereafter, he was placed on a high protein, high caloric diet which was to his liking, principally in the form of amigen or "nutramigen" given in a drink. On this regimen he slowly gained weight. His plasma protein concentration during the first week was 5.6 Gm per hundred cubic centimeters, with albumin 3.5 Gm and globulin 2.1 Gm. At the end of two months this had fallen only slightly, the level never going below 5 Gm for protein and 3 Gm for albumin. Subsequently the plasma protein remained at this level. His hemoglobin content was 99 per cent during the first week, it fell gradually to 78 per cent at the end of nine weeks and then remained between 80 and 90 per cent thereafter. One transfusion of 500 cc of blood was given in the ninth week. The osteomyelitis of the femur became active intermittently during his course, as shown by slight purulent discharge which occurred without other evidence of infection in the old wound. Grafting was done for the first time in the eighth week without success. Regrafting two months later was completely successful. The data on vitamins are given in chart 5.

During the first six weeks the patient received no vitamin supplements, but thereafter he received 1 Gm of ascorbic acid, 10 mg of riboflavin, 10 mg of thiamine and 70 mg of nicotinamide daily.

The fasting plasma ascorbic acid concentration was between 0.2 and 0.3 mg per hundred cubic centimeters during the first three weeks and then fell to zero during the sixth week. The daily rates of fasting hourly excretion during this time were also low, varying from 0.3 to 1.2 mg per hour. After the supplement of 1 Gm of ascorbic acid daily was given, the fasting plasma ascorbic acid concentration rose to from 0.5 to 1.0 mg per hundred cubic centimeters and the daily rate of fasting hourly excretion to from 3.7 to 11.2 mg per hour.

During the first four weeks, the fasting hourly excretion rate of riboflavin was low, but it then rose to normal values in the fifth week (about 50 micrograms per hour) before supplements of riboflavin were given. Thereafter, with a daily supplement of 10 mg of riboflavin the excretion varied between 50 and 80 micrograms per hour.

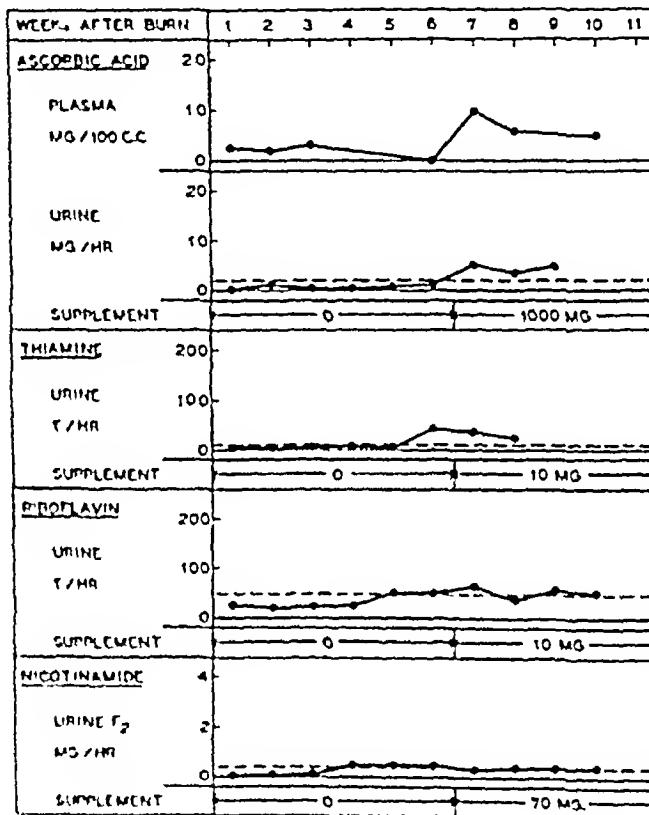
During the first five weeks, the fasting hourly excretion rate of thiamine was slightly low, but it rose to high normal values in the sixth week (about 40 micrograms per hour) before supplements of thiamine were given. Thereafter, on a daily supplement of 10 mg of thiamine the fasting hourly excretions varied between 20 and 40 micrograms.

During the first three weeks, the fasting hourly excretion rate of N-methylnicotinamide was 0.1 to 0.2 mg. Subsequently, the rate was about 0.5 mg per hour and did not change significantly when a supplement of 70 mg of nicotinamide was given.

As noted previously, grafting in the eighth week was unsuccessful. We believe that although the vitamin deficiencies were corrected prior to the first grafting the protein deficiency had not been corrected and

the graft failed for this reason. Two months later, at which time the patient was in good nutritional status, grafting was completely successful.

CASE 17—W. W., a 60 year old man, was admitted to the hospital shortly after receiving flame burns of his back and arms when he fell asleep smoking a cigarette in bed while intoxicated. During the year prior to entry, the patient had been on an extremely poor diet and had consumed fairly large quantities of alcohol. He had had bloody diarrhea for the six months preceding entry and during this time had lost 10 pounds (4.5 Kg.) in weight. There had been no ascites, jaundice or edema of the ankles. His past history was otherwise noncontributory.



In the third week the patient was put on a high protein, high caloric diet, given by means of intubation. He had in addition received large doses of vitamins intramuscularly from the second week. The diarrhea and the guaiac-positive stools decreased and finally disappeared. His temperature throughout the first two months ranged between 98.6 and 100 F and thereafter rarely went above 99 F. One month after his entry to the hospital incision and drainage of a moderate-sized abscess over the right deltoid were done. His weight three weeks after entry was 119 pounds (54 Kg). This had fallen to 110 pounds (50 Kg) six weeks later, it gradually rose, reaching 120 (55 Kg) four months after entry, and by the time of discharge was 128 (58 Kg). The first skin graft was done in the ninth week, with complete take, and a small graft to cover the remaining areas was done in the twelfth week. The data on the vitamins are presented in chart 6.

The fasting hourly excretion rates of thiamine and riboflavin during the first week after admission, before any supplements had been given,

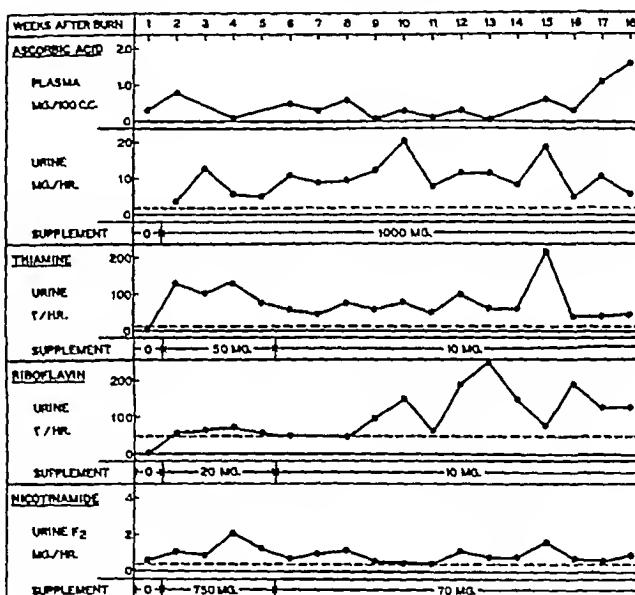


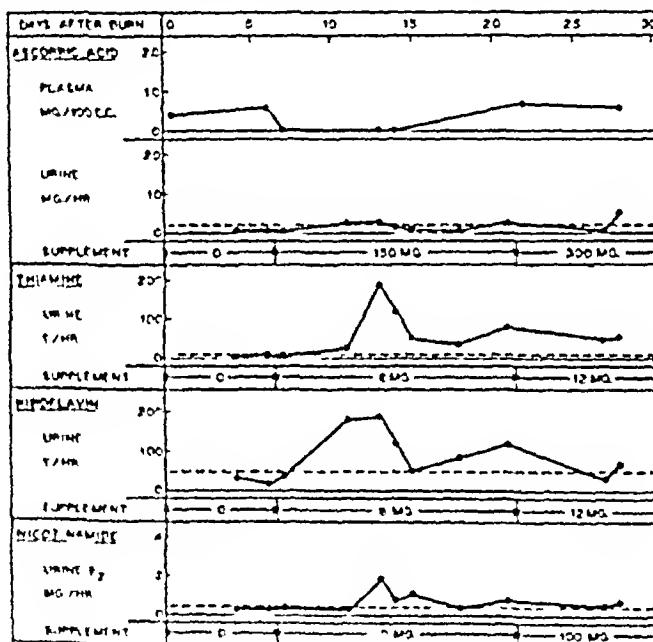
Fig. 6 (case 17).—Plasma ascorbic acid levels and fasting hourly excretion rates of ascorbic acid, thiamine, riboflavin and N-methylnicotinamide in an adult with a minor deep burn complicated by alcoholism and chronic colitis of probable nutritional origin.

were somewhat below the average for normal persons on a nonsupplemented diet. The excretion of N-methylnicotinamide was normal, and the fasting plasma ascorbic acid concentration was 0.3 mg per hundred cubic centimeters.

From the second through the eighteenth week the patient received 1 Gm of ascorbic acid daily. The plasma ascorbic acid level varied between 0.1 and 0.8 mg per hundred cubic centimeters from the second to the ninth week. During the next five weeks the levels varied between 0.0 and 0.3 mg. By the seventeenth week the level had risen to 1.1 mg and it rose to 1.6 mg per hundred cubic centimeters in the eighteenth

The fasting hourly excretion rate of ascorbic acid varied between 3.8 and 21 mg, with no definite correlation with the plasma vitamin C levels. After the eighteenth week the supplement of ascorbic acid was reduced to 225 mg daily. The plasma ascorbic acid level fell to 0.6 mg per hundred cubic centimeters, and the excretion fell to from 0.7 to 2.1 mg per hour. The fasting hourly excretions of thiamine, riboflavin and N-methylnicotinamide with the patient on the large supplements were well above the average excreted by normal persons on a nonsupplemented diet and comparable to the excretions of normal persons given high supplements.¹¹

We believe that the success of the first skin graft in this case, as compared to those in cases 15 and 16, was due to the fact that the



had extensive deep dermal or deep burns, and all showed striking abnormalities in vitamin metabolism, as detailed in the following reports.

CASE 19—J. B., a 42 year old white woman with a noncontributory past history, was admitted to the hospital shortly after receiving flame burns, chiefly deep dermal, of 20 per cent of her body surface and moderately severe damage to the respiratory tract. Examination on admission revealed a fairly well developed and well nourished woman whose systolic blood pressure was 85. She was given plasma and whole blood intravenously. The blood pressure promptly rose to 110 systolic and 70 diastolic and remained satisfactory thereafter. Her temperature rose gradually, reaching a level of 102 F on the sixth day in the hospital, but fell to 100 F by the eighth day, at about which level it remained for the next two months. Her appetite was good, and in addition to her food she received protein hydrolysate and dextrose intravenously. Her weight, plasma protein concentration and hemoglobin concentration were maintained.

Most of the burn was extremely deep dermal burn, and it healed slowly, after superficial sloughing, in about nine weeks. Two weeks later, deep phlebitis of the

TABLE 6—"Low" Saturation Tests of Vitamin Excretions in Four Hours in a Patient Studied (Case 19)*

Day	Ascorbic Acid, Mg	Thiamine, Mg	Riboflavin, Mg	N Methyl nicotinamide, Mg
0†	28	0.5	1.0	5.4
6	14	1.0	1.0	11.5
18	7	1.0	1.0	5.5
27	58	1.8	0.7	8.0
41	50	8.2	1.2	8.0
48	104	2.1	0.6	10.7
70	60	1.2	0.8	15.9

* The test doses given (intravenously) were ascorbic acid, 250 mg, thiamine, 5 mg, riboflavin, 8 mg, and nicotinamide, 50 mg.

† Day of injury.

right leg and one small pulmonary infarct developed. She recovered from this without further complications in about a week. Skin was grafted over the remaining granulating area on the back in the fourteenth week. A complete take resulted. Her further course was benign, and she was discharged two weeks later. The data on the vitamins are given in charts 7 and 8.

During the first week, the patient received no vitamin supplements. Fasting hourly excretions of thiamine and riboflavin were slightly below the average for normal persons on a nonsupplemented diet. Thereafter she received a supplement of 6 mg each of thiamine and riboflavin daily for the next two weeks and then 12 mg daily of each. The fasting hourly excretion levels rose and were within the range of values found for healthy persons receiving large supplements of these vitamins. The excretion of N-methylnicotinamide was about 0.3 mg per hour during the first week, and it rose thereafter to levels of 0.5 to 1.0 mg on supplements of 50 to 100 mg of nicotinamide daily. Results of low saturation tests of thiamine, riboflavin and N-methyl-nicotinamide performed on the first, sixth, thirteenth, twenty-seventh,

forty-first, forty-eighth and seventy-sixth day were essentially normal except for a slightly low excretion of thiamine on the first test. Table 6 gives the results of these tests.

During the first week, no supplement of ascorbic acid was given. The plasma level, which was 0.4 mg per hundred cubic centimeters on the first day, fell to zero by the seventh day. Fasting hourly excretions during this week were also low, averaging about 0.6 mg. Saturation tests, with 250 mg of ascorbic acid as the test dose, performed on the day of entry and again on the sixth day after entry revealed plasma levels and excretion values which were considerably lower than normal and in fact, similar to those seen in patients with scurvy. During the second and third weeks, the patient received a supplement of 150 mg of ascorbic acid daily. The plasma vitamin C concentration remained exceedingly low. The rate of fasting hourly excretion rose during the second week to 2.2 mg and then fell again to 0.8 mg during the third

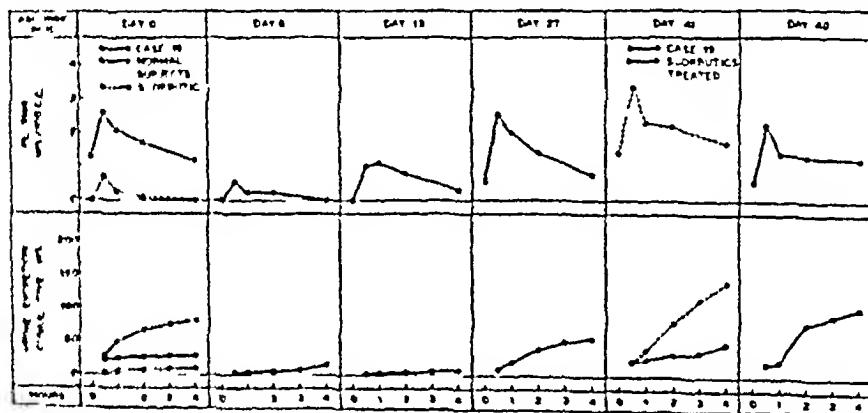


FIGURE 19.—Serial ascorbic acid saturation tests in an adult with extensive deep dermal burn. The test dose was 250 mg given intravenously.

CASE 20—J. R., a 27 year old white man, was admitted to the hospital shortly after receiving extensive flame burns involving 40 per cent of the body surface, the burn being chiefly deep. For the year or two prior to his entry he had been drinking large amounts of alcohol but apparently had also been eating fairly well. Examination revealed a well developed, apparently fairly well nourished man who was somewhat disoriented and delirious. On entry the blood pressure was 90 systolic and 70 diastolic and the pulse was of good quality. The blood pressure and the pulse thereafter were normal, and there was no period of shock. During the first twenty-four hours he received 3,750 cc. of plasma and 5 liters of other fluids intravenously, chiefly isotonic solution of sodium chloride. The urine output during the first twelve hours was 1,000 cc.

Shortly after entry the patient went into delirium tremens, the temperature having risen to 105.6 F rectally on the second day. The respirations at this time were 45, and the pulse rate was 145. He was given large amounts of vitamins (details of vitamin therapy are given later), paraldehyde and intravenously administered amigen, dextrose and isotonic solution of sodium chloride. He was also given a high protein, high caloric intake by mouth and by intubation. The delirium tremens was finally controlled after five days. The temperature continued to be elevated, reaching 104.5 F rectally. The respirations fluctuated between 30 and 50 and were occasionally labored. He was coughing and raising thick yellow sputum. The chest could not be examined satisfactorily by either physical or roentgenologic examination because of the burns and dressings. He was given full doses of sulfadiazine (6 Gm a day) and 20,000 units of penicillin intramuscularly every two hours. Two weeks after entry he was placed in an oxygen tent for possible cooling effects and in an attempt to relieve some of the respiratory distress.

His condition gradually became worse, and three weeks after his entry to the hospital the temperature rose suddenly to 108 F and he became comatose. The respirations were shallow and rapid, his pupils were unequal in size and there appeared to be slight facial weakness on the right side. The neurologic consultant suggested the possibility of a brain abscess. He was sponged vigorously with cold alcohol, and the temperature dropped to 104 F. However, he gradually became weaker and died on the following day.

During the first five days, there had been moderate negative nitrogen balance; thereafter, his intake of nitrogen was gradually increased and reached a level of about 40 Gm a day by the ninth day. At this time his caloric intake was 3,500. There was then slight apparent positive nitrogen balance. This high intake of nitrogen continued until the twenty-first day, when his intake diminished to less than one half of this amount, and there was slight negative balance again.

The plasma protein concentration was 3.5 Gm. per hundred cubic centimeters on the first day, with an albumin level of 2 Gm. This rose gradually to a level of 5.0 Gm. on the tenth day, but the albumin remained at 2.1 Gm. The plasma protein concentration on the twentieth day was 5.4 Gm. His hemoglobin content, which had been 119 per cent on entry, fell to 64 by the tenth day and thereafter ranged between 62 and 79 per cent. He was given multiple transfusions of 500 cc. of whole blood.

Studies of vitamin excretion were not done. He received an average of 50 mg of thiamine, with extremes of 20 to 60 mg, 20 mg of riboflavin, with extremes of 10 to 40 mg, and 500 mg of nicotinamide, with extremes of 100 to 800 mg, daily after the first day, chiefly by the intramuscular route. The lower doses in each instance were given from the sixth to the eleventh day. Fasting plasma ascorbic acid concentrations were measured, and the data are given in chart 9.

During the first five days the patient was given an average of 1 Gm of ascorbic acid intramuscularly daily. During this time the plasma ascorbic acid concentration ranged from 0.3 to 0.7 mg per hundred cubic centimeters. From the sixth to the twelfth day he was given an average of 500 mg of ascorbic acid intramuscularly and 225 mg orally. During this time the plasma ascorbic acid concentration fell, being zero on the eleventh day. Therefore he was given 2 Gm intramuscularly daily as well as 225 mg by mouth. It was only after two days of this high intake that a measurable amount of ascorbic acid appeared in the plasma. This indicates that the patient's store had become markedly depleted during the preceding week despite the fact that he had been given a supplement of 750 mg of ascorbic acid daily.

CASE 21—J. V., a 35 year old white man with a noncontributory past history, was admitted to the hospital shortly after receiving flame burns, chiefly deep, involving 40 per cent of his body surface. The accident occurred when he fell asleep smoking a cigarette while intoxicated. Examination on entry revealed him

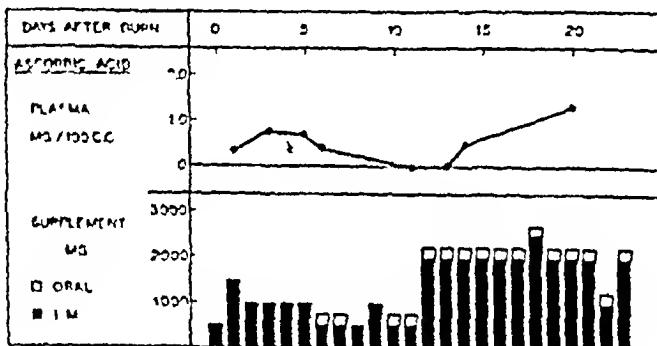


Fig. 20 (case 20).—Nitrogen balance and plasma ascorbic acid concentration in a patient with an extensive total deep burn.

concentration fell from a level of 5.8 to 4.7 Gm and the albumin from 4.1 to 3.3 Gm His hemoglobin content was 85 per cent

The first dressing was done on the morning of the eighth day Dry adherent slough was present over most of the burned areas There was no surrounding redness, swelling or tenderness A dry pressure dressing was reapplied Six hours later he was much sicker His temperature had risen to 104 F rectally, the pulse rate was 140 and the respirations 25 He was irrational The dose of penicillin was increased to 20,000 units every two hours The following morning the temperature had risen still further to a level of 108 F and the pulse rate to 160 The respirations remained at 28 but were somewhat shallow He had a

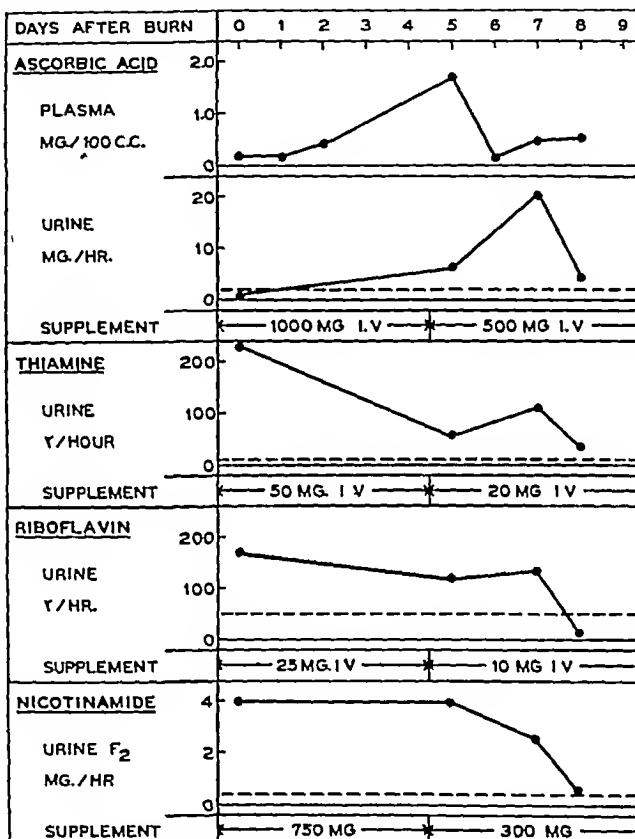


Fig 10 (case 21)—Plasma ascorbic acid concentration and fasting hourly excretion rates of ascorbic acid, thiamine, riboflavin and N-methylnicotinamide in an adult with an extensive fatal deep burn

moderate nonproductive cough. Continuous sponges with iced alcohol were started and sulfadiazine was given He was placed in an oxygen tent The temperature came down to 104 F and the pulse rate to 130 within a few hours, but the following day the temperature rose again, this time to a level of 109 F, and the patient died shortly thereafter

The data on the vitamins are shown on chart 10

During the first five days the patient was given a daily supplement of 1,000 mg of ascorbic acid, 50 mg of thiamine, 20 mg of riboflavin

and 750 mg of nicotinamide. The fasting hourly excretion rates on the first day were normal for thiamine, riboflavin and nicotinamide but slightly low for ascorbic acid. Determinations after the fifth day showed levels which were all above the average for healthy persons on a normal diet but seemed low for the large dosage which the patient was receiving.

The level of plasma ascorbic acid two hours after the burn and before any additional ascorbic acid was given was 0.16 mg per hundred cubic centimeters. Ten hours later, seven hours after 1 Gm had been given intravenously this level was unchanged. Twelve hours later, fifty minutes after another grain had been given intravenously, the level was 2.08 mg. By the fifth day the fasting plasma ascorbic acid level had risen to 1.70 mg per hundred cubic centimeters, the patient having received 1 Gm of ascorbic acid daily. Therefore, with a supplement of 500 mg daily the ascorbic acid level fell to 0.2 mg on the sixth day and 0.5 mg on the seventh and eighth days. These values are considerably lower than those observed in normal persons receiving 500 mg of ascorbic acid daily.

on admission Her burn was minor She remained on a diet low in vitamin C for six weeks, and during this time the fasting hourly excretion rate of ascorbic acid and the fasting plasma ascorbic acid concentrations were low The excretion of the other vitamins was normal A skin graft at this time failed Thereafter she received a supplement of 1 Gm of ascorbic acid daily, and the plasma vitamin C level and the urinary excretion rose to normal A skin graft at this time was completely successful

Another patient who entered the hospital with probable preexisting vitamin deficiency was the patient in case 17, a 60 year old man who for a period of six months prior to entry ingested a poor diet and large quantities of alcohol and suffered from intermittent bloody diarrhea On entry to the hospital he was moderately underweight, but there were no definite stigmas of specific vitamin deficiency His burn was of moderate severity During the first week, the urinary excretions of thiamine, riboflavin and n-methylnicotinamide were low (excretion of ascorbic acid not measured) and the fasting plasma ascorbic acid levels were also low Thereafter he was given large daily supplements of all vitamins, and the urinary excretions of the four vitamins and the plasma ascorbic acid concentration rose to normal levels The third patient who entered the hospital with probable preexisting nutritional deficiencies, although none were apparent on entry, was the patient in case 20 He was a 27 year old man who had had alcoholism for the year previous to injury Despite a daily supplement of 750 mg of ascorbic acid daily, chiefly by the intramuscular route, his plasma ascorbic acid concentration fell to zero in the second week and remained at this level even after 4 Gm of ascorbic acid had been given in two days This would indicate that some factor in addition to possible preexisting deficiency was present in this patient, since the experiments of Crandon, Lund and Dill¹⁶ showed a much more rapid rise in the plasma ascorbic acid after actual scurvy had been treated with comparable amounts of vitamin C In the other cases studied preexisting deficiency did not play an important role

2 Inadequate Dosage—In a few patients the intake of the various vitamins was probably low and may have accounted in part for the finding of low excretion values However, in the patients with the most pronounced abnormalities the actual intake of vitamins was extremely high—far above the so-called optimum amount for healthy persons

3 Failure of Absorption—Failure of absorption can be ruled out by the fact that in the most severely burned patients, who showed the

¹⁶ Crandon, J H, Lund, C C, and Dill, D B Experimental Human Scurvy, New England J Med 223:353-369, 1940

during their destruction. This study contributes no evidence for or against such a postulate.

9 *Increased Utilization*.—It has been shown in recent years that many of the vitamins play more fundamental roles than merely the prevention or curing of the well known deficiency syndromes such as scurvy, beri-beri and pellagra. Thiamine, riboflavin and nicotinic acid are concerned with the enzyme systems that control carbohydrate metabolism, and in addition riboflavin is important in amino acid metabolism. Ascorbic acid has been shown to have a fundamental role in the formation of the adrenocortical hormone¹⁹ and in general tissue metabolism. These functions indicate that the four vitamins play important roles in connection with recovery from hemorrhagic shock,²⁰ injury and acute infections,²¹ since disturbances in the metabolism of carbohydrate,²² protein and adrenocortical hormones are found in these conditions. Thus, Govier²³ has found that the mortality of normal dogs exposed to a standardized type of hemorrhagic shock was reduced when thiamine was given in large doses before or after bleeding. In addition, dogs deficient in thiamine were particularly susceptible to death from hemorrhagic shock. Holt²⁴ has demonstrated apparent increased utilization of thiamine in conditions of stress such as increased basal metabolism and fever. On the other hand, Bergman and others²⁵ were unable to show any beneficial effect of thiamine or ascorbic acid used alone as sole therapeutic measures in the treatment of shock due to scalding burns in mice. In the later period of burns, when epithelization and formation of granulation tissue are taking place, it is probable that there is an increased demand for ascorbic acid and riboflavin and possibly for other vitamins.

19 Sayers, G., Sayers, M. A., Liang, T., and Long, C. N. H. The Effect of Pituitary Adrenotropic Hormone on the Cholesterol and Ascorbic Acid Content of the Adrenal of the Rat and the Guinea Pig, *Endocrinology* **38** 1-9, 1946.

20 Russell, J. A., Long, C. N. H., and Engel, F. L., Biochemical Studies on Shock. Role of Peripheral Tissues in Metabolism of Protein and Carbohydrate During Hemorrhagic Shock in Rat, *J. Exper. Med.* **79** 1-7, 1944.

21 Davidson, C. S., Lewis, J. H., Tagnon, H. J., Adams, M. A., and Taylor, F. H. L. Medical Shock. Abnormal Biochemical Changes in Patients with Severe Acute Medical Illnesses, With and Without Peripheral Vascular Failure, *New England J. Med.* **234** 279-288, 1946.

22 Aub, J. C., and Wu, H. Studies in Experimental Traumatic Shock III. Chemical Changes in Blood, *Am. J. Physiol.* **54** 416 (Dec) 1920.

23 Govier, W. M. Rationale for Use of Vitamins in the Therapy of Shock and Anoxia, *J. A. M. A.* **126** 749-750 (Nov 18) 1944.

24 Holt, L. E., Jr. The Thiamin Requirement of Man, *Federation Proc.* **3** 171-178, 1944.

25 Bergman, H. C., Rosenfeld, D. D., Hechter, O., and Prinzmetal, M. Ineffectiveness of Adrenocortical Hormones, Thiamin, Ascorbic Acid, Nupercaine, and Post Traumatic Serum in Shock Due to Scalding Burns, *Am. Heart J.* **29** 506-512 (April) 1945.

ALUMINUM HYDROXIDE AND MAGNESIUM TRISILICATE PLUS MUCIN IN TREATMENT OF PEPTIC ULCER

Gastroscopic and Clinical Studies

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Clinical study has shown that antacids are the most important single factor in controlling gastric pain and discomfort due to hyper-acidity and peptic ulcer. A review of medical literature and advertisements by pharmaceutical companies reveals that physicians have been led to believe that antacids, especially aluminum gels and magnesium trisilicate, have an astringent and protective coating action on the gastric mucosa. There has been no definite proof brought forward to substantiate or refute the suggestion that aluminum gels have an astringent or coating effect on the mucosa of the stomach.

Ivy and his associates¹ have called attention to the fact that the aluminum combines with the gastric mucus to form a flaky precipitate, which adheres to the mucosa of the stomach and duodenum. A film of this nature would serve as a physical protection to the mucosa and exert an antacid action as well. In animals that had received the aluminum preparations for some time, they observed at autopsy that the folds of the mucosa in the stomach and duodenum were covered with flaky curds, presumably precipitated mucus. At times the duodenum was so coated that about two thirds of the mucosa appeared as if it had been covered with flour paste.

Fogelson² in 1931 was the first to advocate gastric mucin in the treatment of peptic ulcer. This treatment met with disfavor chiefly because of its nauseating taste and because the commercial products at that time contained histamine in such quantities as to increase decidedly the gastric acidity.

Fogelson³ also showed that mucin had a retarding effect on pepsin activity.

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1 Ivy, A C, Terry, L, Fauley, G B, and Bradley, W B Am J Digest Dis 3 879, 1937

2 Fogelson, S J Treatment of Peptic Ulcer with Gastric Mucin, JAMA 96 673 (Feb 28) 1931

3 Fogelson, S J Illinois M J 62 516, 1932

Jones,⁴ as well as many other authors, claimed that the beneficial effects of the aluminum hydroxide gels are largely the result of their astringent action. Page and Thomas⁵ observed that magnesium trisilicate acquires gelatinous consistency in the presence of acid and if it lodges in the ulcer crater will progressively neutralize the acid which diffuses through it.

We have gastroscopically observed the physical appearance in the stomach of four of the well known proprietary aluminum gels, of magnesium trisilicate and of calcium carbonate. Thirty-five patients were used in this study—in 15 the stomach had been previously diagnosed as normal, 3 had been given a diagnosis of hypertrophic gastritis, 5 atrophic gastritis, 9 duodenal ulcers and 3 gastric ulcers. The patients were without food for twelve hours prior to gastroscopy. The gastric contents were aspirated in all but 10 of the patients before instillation of the antacid, in order to remove any stomach contents that might still be present after the twelve hour fast. The antacids were given in half ounce doses five, fifteen, thirty and forty-five minutes respectively, prior to gastroscopy.

There was no essential difference in the appearance of the antacids in those patients in whom the gastric contents were aspirated and in those in whom aspiration was not done. From five minutes to half an hour after instillation the antacid appeared as a large white irregular mass or broken up into smaller clumps and scattered irregularly throughout the stomach. The speed with which the antacid left the stomach was variable. At the end of twenty to forty-five minutes we frequently noted, especially when liquid preparations were used, that there was a total absence of antacid in the stomach. This observation was confirmed by roentgenologic studies in which we added sufficient barium sulfate to the liquid antacid preparations to visualize the antacid. Roentgenograms were taken at twenty minute intervals, and it was noted in some instances that the barium sulfate antacid preparation was absent at the end of forty minutes (fig. 1). The antacids, as seen gastroscopically, were scattered throughout the stomach in clumps of various sizes and could not be differentiated one from the other. We did not get the impression that any of the antacids employed in this study had a distinct coating effect. In a few instances in which there was an increase of mucus in the stomach, there seemed to be a slight tendency for the aluminum gels to diffuse through the mucus which adhered to the walls of the stomach.

In 3 of the patients in whom aspiration had not been done and in 5 in whom aspiration had been done prior to gastroscopy and to instillation of the antacid, there was considerable mucus present in the

⁴ Jones, C R, Jr. Pennsylvania M J 43:468, 1940.

⁵ Page, R C, and Thomas, E G. Mil Surgeon 85:307, 1939.

stomach. The aluminum gels seemed to diffuse through the mucus and appeared to be suspended in a finely divided state, clinging or adherent to the mucosa in thick strings which extended from the anterior and posterior walls of the stomach. Increased amounts of mucus appeared to delay the exodus of aluminum gels from the stomach. With small amounts of mucus there was no essential difference in the physical properties of the calcium carbonate, magnesium trisilicate or aluminum hydroxide.

Our observations gastroscopically substantiated those of Ivy and his associates and led us to the conclusion that a coating effect is obtained only when sufficient gastric mucus is present to allow the aluminum gels or magnesium trisilicate to diffuse through it and remain clinging to the walls of the stomach in a filmlike coating. We inferred from this



Fig. 1.—Roentgenogram of the stomach twenty minutes after ingestion of 20 g. of aluminum hydroxide with magnesium trisilicate gel. The empty at the end of forty minutes.

there should be a combination of aluminum gels and/or magnesium trisilicate with gastric mucin in order to insure a sufficient amount of adhesion in the stomach when the antacid is instilled. In the presence of a sufficient amount of gastric mucin, aluminum gels and magnesium trisilicate tend to diffuse through the gastric mucin and in this manner produce a protective coating action.

We then decided to study in a similar manner, gastroscopically and roentgenologically the physical appearance of a mixture containing magnesium trisilicate and aluminum hydroxide to which was added from 10 to 20 per cent of gastric mucin.⁶ Three patients with gastric

⁶ The preparations used were palatable and free from secretagogue action.

ulcer, 5 with atrophic gastritis and 11 with normal stomachs were used for this purpose. Gastroscopic observations were made before the instillation of this mixture and again twenty minutes to an hour and a half after the mixture was instilled. A vegetable dye was added to the mixture in several instances as a further means of identification and assurance that the physical appearance of the mixture was not due to the presence of normal gastric mucus.

The mucin antacid mixture was administered in the form of a palatable powder or tablet, thoroughly chewed and swallowed without the use of water. Gastroscopic observations were made at intervals of half an hour to an hour and a half after instillation of the mucin antacid. Invariably we were able to demonstrate a decided tendency toward



Fig. 2.—Roentgenogram of the stomach twenty minutes after ingestion of barium sulfate plus mucin antacid mixture. The mixture is still present at the end of one hour and forty minutes.

coating and filming of the mucosa. Our most striking results were obtained in the patients suffering from gastric ulcer. The ulcer crater in each instance was covered by a pool of the antacid mixture, and the mucosa surrounding the ulcer had a thick, filmy coating. The mucin antacid was observed gastroscopically to be present in the stomach as long as an hour and forty minutes after instillation. This we confirmed roentgenologically by adding barium sulfate to the mixture and taking roentgenograms at twenty minute intervals (fig. 2).

This mucin antacid mixture has been tested for its effect on gastric acidity and has been compared with two currently used aluminum gel preparations and a powder containing calcium carbonate and sodium

NEWER ASPECTS OF BENIGN TUMORS OF THE BREAST

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BENIGN tumefactions of breast tissue and its integument may be divided into A Mammary dysplasia, resulting from abnormalities in the secretion of the ovarian hormones This is exemplified by

- (1) Mastodynia—painful mammary tissue of increased density
- (2) Adenosis—nodosities from epithelial hyperplasia with small cysts
- (3) Cystic disease—one or more cysts of appreciable size resulting from secretory changes

B Benign neoplasia, characterized by true benign tumor formations Examples of this are

- (1) Benign fibroadenoma with a structure of fibrous tissue and ducts
- (2) Benign intracystic papillomas, which include (1) papillary invaginations of larger ducts, (2) intracystic papillomas and (3) papillary hyperplasia which occurs in adenosis of the breast
- (3) Benign nonindigenous tumors of the breast, involving (a) fat (lipoma and xanthoma), (b) lymphatic vessels (angioma, lymphangioma and lymphoma), (c) muscles (leiomyoma and myoblastoma), (d) skeletal mesenchyme (chondroma and osteoma) and (e) skin appendage (dermoid cysts and sweat gland tumors)

This classification is taken from that of Geschickter and is considered to be extremely practical

This paper is concerned with benign tumefactions of the breast proper, namely, mammary dysplasia and mammary neoplasia (benign)

A MAMMARY DYSPLASIA

Mammary dysplasia is neither inflammatory nor neoplastic but represents an expression of ovarian dysfunction in menstruating women This point of view has not gone unchallenged Taylor¹ and Friedman and

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¹ Taylor, H C, Jr. The Evidence for an Endocrine Factor in the Etiology of Mammary Tumors, Am J Cancer 27 525, 1936, The Endocrine Aspects of Chronic Mastitis, Surg, Gynec & Obst 74 326, 1942

others² in independent studies concluded that dysplasia was related to ovarian dysfunction in some cases, but they felt that this condition must be referred to a variety of factors, among which the nervous disturbances depending mainly on pelvic disorders were prominent Ewing,³ from a review of the literature and from his own observations, concluded that mammary dysplasia (chronic cystic mastitis) has notably a hereditary character, the main etiologic factor residing in the intrinsic character of the breast itself influenced more or less by hormonal, nervous and local conditions.

Bucher and Geschickter,⁴ however, have followed patients intensively by doing endocrine assays on total collections of the daily urine through one or more menstrual cycles. Both estrogen and pregnandiol (an index of corpus luteum function) were assayed. The results of these studies together with the results of experimental studies by Geschickter and others on the production of mammary dysplasia, mammary neoplasia, and cancer resulting from prolonged overstimulation with estrogen strongly support ovarian dysfunction as a principal cause.

Estrogen in varying dosages combined with other hormones which produce lobule formation appears to produce experimentally changes in animals simulating the various changes seen in chronic cystic mastitis.

Many observers⁵ support a definite endocrine factor as being linked with mammary dysplasia, benign mammary neoplasia and the production of carcinoma of the breast.

Mastodynia.—Mastodynia is common in women between the ages of 20 and 40 years. Married women who become affected predominate over unmarried women in the ratio of 3 to 1. It is characterized by pain, which is gradual in onset over a period of months. The pain is

2 Friedman, M., Finkler, R., and Antopol, W. The Relation of Ovarian Hormones to Benign Breast Hyperplasia and Neoplasia, *Radiology* **33** 725, 1939.

3 Ewing, J. Hormonal Relations of Chronic Mastitis, in *Neoplastic Diseases*, Philadelphia, W. B. Saunders Company, 1940, p. 538.

4 Bucher, N., and Geschickter, C. F. Corpus Luteum Studies I Recovery of Pregnanediol from Urine, *Endocrinology* **27** 727, 1940, II Pregnanediol and Estrogen Output in the Urine of Patients with Chronic Cystic Mastitis, *J. Clin. Endocrinol.* **1** 58, 1941.

5 (a) Geschickter, C. F. Chronic Cystic Mastitis or Mammary Dysplasia, in *Diseases of the Breast*, Philadelphia, J. B. Lippincott Company, 1945, pp. 183-260 (b) Astwood, E. B., and Geschickter, C. F. Changes in the Mammary of the Rat Produced by Various Glandular Preparations, *Arch. Surg.* **36** 672 (April) 1938 (c) Bonser, G. M. The Effects of Estrone on the Mammary Gland of Male Mice, in *Second International Congress Against Cancer*, 1937, p. 53 (d) Gardner, W. U. Influence of Oestrogenic Hormones on Abnormal Growth, in Ward, H. B. Some Fundamental Aspects of the Cancer Problem, American Association for the Advancement of Science, New York, The Science Press, 1937, p. 67 (e) Nathanson, I. T. The Relation of Hormones to Diseases of the Breast, *Surgery* **16** 108, 1944 (f) Bucher and Geschickter⁴

worse in the premenstruum and is referred to a portion of the breast (usually the outer and upper third) which is more tender, firmer, thicker and more granular than the surrounding breast. It may be unilateral or bilateral.

The patients may fall into two endocrine groups:

(1) Women in the childbearing age who have a tendency toward sterility and who have not been recently pregnant. The breasts are well developed, the menstrual history is normal and the disturbance in the breasts comes late after maturity and is usually transient.



Fig 1.—Photomicrograph of typical mastodynia tissue. (All illustrations except figures 2 and 3 by courtesy of Dr C F Geschickter and the J B Lippincott Company, from Diseases of the Breast, Philadelphia, J B Lippincott Company 1943.)

(2) Young childless women with small atrophic breasts. The menses are irregular, and they are frequently sterile. Pelvic inflammatory disease is not infrequently encountered. The breasts suggest a primary mammary deficiency dating from shortly after adolescence.

The fear of cancer in the mind of the patient or of the physician has afforded many pathologic specimens to be observed. Grossly, the tissue is nonencapsulated, dense and fibrous. Small cysts may be present. Histologically (fig 1) there is imperfect lobule formation and an increase in periductal and intralobular stroma. Irregular epithelial growth is noted in the terminal tubules, which may be dilated.

The defective lobule formation, as demonstrated in recent studies,^{5a} is due to reduced function of the corpus luteum, which in some patients may be a relative lowering of the function or excessive stimulation by the estrogenic hormone. Normal lobule formation is dependent on the proper ratio of estrogen and luteal hormones.

Treatment The treatment of mastodynna is varied. Once the diagnosis of cancer or true infection has been ruled out, simple supportive measures are worth while, including reassurance and a breast support (brassiere). Estrogen in doses of 10,000 international units intramuscularly once a week between two periods and then 2,000 units once a month in the premenstruum for a limited time has proved effective in controlling the condition. Testosterone propionate in doses of 25 mg. per week for a short while has proved satisfactory in a few cases. Progesterone therapy has proved to be the treatment of choice. Patients have shown improvement when progesterone has been administered in 5 mg. doses hypodermically twice a week for the last two weeks of one or two consecutive cycles, with an effective total dose ranging between 20 to 40 mg.

Endocrine therapy has yielded remarkable results in many cases, two or more years having elapsed after its use without recurrence of symptoms. It is strongly recommended.

Other forms of treatment have varied from simple reassurance to the performance of mastectomy.

Adenosis—Adenosis (Schimmelbusch's disease) is most frequently observed in women between the ages of 35 and 44 years. It is characterized by the occurrence in one or both breasts of multiple nodules which measure from 1 mm. to 1 cm. in diameter and are usually distributed about the upper and outer hemisphere. In one third of the patients pain is a conspicuous feature. The breasts, as in mastodynna, are thickened, granular and tender, with the additional occurrence of multiple nodules. An edge can be palpated at the periphery of the diseased portion. This "caking" or induration may at times suggest cancer.

Adenosis is often superimposed on a persisting mastodynna and is much more chronic and more intractable to treatment.

The differential diagnosis from benign intracystic papilloma or from mammary cancer may require a biopsy.

The pathologic process may be limited or diffuse throughout the breast or breasts (figs. 2 and 3). Increased fibrous tissue through the parenchyma riddled with small cysts, minute adenomas, papillomas and dilated ducts is characteristic. There is much increase in the periductal and perilobular stroma. The intraductal hyperplasia and the epithelial proliferation of acini resemble those in various forms of cancer.

There is a definite relation between adenosis, mastodynia and cystic disease of the breast. Tissue excised from a patient with adenosis may show cysts, and that excised from a patient with cystic disease may show small areas of adenosis.

The patients fall into two endocrine groups (a) Patients in early sexual maturity with small breasts due to stunting from high estrogenic



Fig 2.—Specimen cross section and photomicrograph in a typical case of adenosis. The mammary tissue is fibrous, firm, contains small cysts in the periphery.

stimulation in adolescence. They may be in a relatively far advanced stage of the disease in their early twenties and may have an increased susceptibility to cancer (b) Patients of 30 years of age or more, who have characteristic changes in the breast of one year's duration or more with pain and menstrual complaints and who are usually psychically



Fig 3.—Photomicrographs showing intracystic papillomas and diffuse proliferation of lobule epithelium in adenosis of the breast.

upset These symptoms are common in both groups, but in this group they seem to be due to a prolonged moderate hyperestrinism brought about by low function of the corpus luteum over a period of years The secretion of estrogen is usually found to be within normal limits

While the changes seen in mammary dysplasia are not essential to the development of mammary cancer, they do represent changes due to hyperestrinism which, as observed in a definite percentage of animals, ultimately lead to the development of cancer in the breasts Clinically, Geschickter^{5a} found that among patients with adenosis of the breast who were carefully followed the incidence of cancer was 2 per cent while among those with cystic disease the incidence was 0.79 per cent The incidence of cancer of the breast is definitely higher among women with chronic mastitis than among women as a whole, for whom the incidence is 0.42 per cent⁶

Treatment Therapy in adenosis must be based on an accurate appraisal of the condition Investigation of all doubtful cases is necessary Nodules which are distinct and larger than usual or growing noticeably larger must be excised and sectioned, whether the nodule is cystic or solid

Amputation of the breast to prevent possible development of cancer is not justified On the other hand, biopsies which are difficult of pathologic interpretation or which show early cancer leave no recourse to the physician except that of doing radical mastectomy

Estrogenic therapy is not satisfactory in adenosis Patients with this condition already have a relative hyperestrinism of long standing, which in animal experiments leads to the development of cancer It is, therefore, not considered coincidental that there is an increased incidence of cancer among patients with adenosis of the breast

Progesterone therapy has given symptomatic relief in most of the patients treated, but the small discrete nodules, which are usually cysts, may persist Aspiration of these cysts may be indicated to obliterate them Progesterone is administered in 5 mg doses hypodermically twice a week, from 20 to 60 mg being given as a total dose between two or three menstrual cycles

Recurrence may be encountered after two or more years

Cystic Disease—Women at or near the menopause form the largest group of patients with cystic disease of the breast The greatest incidence is found in women between the ages of 41 and 45 years The

⁶ Warren, S The Relation of Chronic Cystic Mastitis to Carcinoma of the Breast, *Surg, Gynec & Obst* **71** 257, 1940 Lewis, D, and Geschickter, C F The Relation of Chronic Cystic Mastitis to Carcinoma of the Breast, *ibid* **66** 330, 1938

disease predominates in childless women in the ratio of 3 to 2. For women with children at least from four years to a decade has elapsed between the time of the last pregnancy and the onset of the disease.

Few patients with cystic disease have menstrual disorders or difficulties with childbearing. The menstrual disorders encountered are associated with the menopause. Therefore, the fact that a large number of childless women and a large number of women approaching the menopause are affected is a striking etiologic factor from a clinical standpoint.

When assays of the urine for estrogen and pregnandiol were carried out and linked with experiments on controlled rats receiving large injections of estrogen and small injections of progesterone, Geschickter and others⁷ found evidence to support the probability that an intense or unopposed estrogenic stimulus results in the formation of cysts. The period of stimulation may be brief, and the withdrawal of the stimulus, followed by secretory activity, may play a role in the development of the large cysts.

The symptoms of cystic disease usually appear abruptly or are of a relatively short duration, the period being in terms of days or weeks. The chief complaint is the discovery of a lump. A minority of patients notice mild pain, soreness and a burning or sticking sensation prior to the appearance of the cystic lump.

The breasts affected are usually fairly large or adipose. The cysts are usually found away from the periphery of the breast. The tumor is round, smooth, tense and freely movable. Fluctuation can be made out in some cases. Cysts may change in size and tend to disappear in about 7 per cent of the cases. The upper hemisphere is more frequently affected.

In a large number of cases only one cyst of appreciable size is found, but single cysts may be found in both breasts in 11 per cent of the patients.

Multiple cysts are found in one or both breasts in 25 per cent of cases at the first examination. They occur in a slightly younger age group, and the symptoms are similar to those associated with adenosis. This tendency to multiplicity and bilateral involvement certainly suggests an underlying endocrine disturbance, which is further substantiated by endocrine studies of the urine excreted by the patients.

The tumor and the breast can be transilluminated well. The majority of the cysts project into the fat over the breast and are easily aspirated, yielding a cloudy or a serous fluid. A thick, fibrous, walled cyst deep in the breast makes diagnosis difficult, and if aspiration is unsuccessful, exploration should be resorted to.

7 Geschickter ^{sa} Astwood and Geschickter ^{sb} Bonser ^{sc} Gardner ^{sd}

Treatment The treatment of choice is excision of the cysts (84 per cent of the patients are free from further complaints) In 15 per cent of the patients other cysts develop in the breast Recurrent tumors of the breast in patients past the menopause must be held to be suggestive of cancer until accurately diagnosed

At operation the mammary cyst appears as a tense, bluish, walled cyst embedded in dense, fibrous stroma Multiple small cysts and dilated ducts may be seen in the surrounding tissue Lobule structure is poor Microscopically the lining epithelium of the cyst is often replaced by fibrous tissue or the persistent cuboidal epithelium contains



Fig 4—Cystic disease. Cysts centrally located as noted in macroscopic cross section

eosin-staining cytoplasm The surrounding ducts and lobules show involutional changes The lobules are small and undergo dilation or regression The adjoining tubules are dilated and may contain secretion There is a decided increase in fibrous stroma (figs 4 and 5)

Cancer cysts and intracystic papillomas are not the result of this process They more often affect the large ducts near the nipple after the menopause Cancer, however, is found in 0.74 per cent of patients with cystic disease Simple cysts herein described affect the smaller ducts and terminal tubules and occur prior to or during the menopause

Progesterone has apparently been of some value in prevention of the recurrence of cysts in patients with a tendency toward recurrence

after surgical intervention Endocrine therapy should be instituted only when accurate information exists

B BENIGN NEOPLASIA

Fibroadenoma—Fibroadenoma is the most common benign tumor of the breast in young women in the childbearing age. Its firm and



Fig 5—Cystic disease Gross and microscopic cross sections of the cyst wall

encapsulated character⁸ together with its mobility makes the diagnosis relatively easy. The average age at which it occurs is around 22 years

⁸ Bloodgood, J. C. Benign Tumors of the Breast Encapsulated Adenoma, Ann Surg 79: 172, 1924

Gradual enlargement of a single tumor over a period of months or years is the rule. In early adolescence, during pregnancy or toward the menopause more rapid growth has been noted to appear. These are the times when high concentrations of estrogen are found. The tumor also responds to menstruation.

The breast containing the fibroadenoma is usually well developed. While a solitary lesion is usually found, multiple growths may be present. The tumor must be differentiated from cancer, cystic disease or some other rare, firm lesion of the breast. The lack of retraction of the nipple or of atrophy of the skin together with the average age incidence are helpful points in diagnosis. The tumors are composed of a growth of connective tissue is dense in slow-growing tumors but takes on a loose myxomatous character in tumors of rapid growth. The latter group is designated by many authorities as intracanalicular myxoma.⁹

Fibroadenoma has been experimentally produced by Geschickter, Lewis and Hartman¹⁰ in the rat and monkey by stimulating the breasts with high, intensive doses of estrogenic substance. A constant level of the hormone is necessary as fluctuation does tend to produce cysts rather than fibroadenomas. This is in keeping with the observations in women, in whom the growth of fibroadenomas occurs during the periods of adolescence, early pregnancy and the menopause rather than the period of cyclic menstruation.

Treatment. Excision should be done at once in the treatment of these tumors since this makes the diagnosis certain and avoids large tumor growths and the occasional complicating factor of sarcoma or carcinoma. After excision, fibroadenoma may reappear in about 10 per cent of the cases either in the same breast or in the opposite one. Toward the menopause, giant myxoma or fibrosarcoma may develop in fibroadenoma slowly growing over a period of five or six years with rapid enlargement toward the end.¹¹ The tumors are large, with great cystic spaces into which fibrous polyoid masses project. These

⁹ Oliver R L and Major, R C. Cyclomastopathy, A Physiopathological Conception of Some Benign Breast Tumors, with an Analysis of Four Hundred Cases. Am J Cancer 21: 1, 1934

¹⁰ Geschickter, C F, Lewis, D D, and Hartman, C G. Tumors of the Breast Related to the Oestrin Hormone, Am J Cancer 21: 828, 1934

¹¹ Emge, L A, and Murphy, K M. The Influence of Long Continued Injections of Oestrogen on Mammary Tissue, Am J Obst & Gynec. 36: 750, 1938

Owens, F M, and Adams, W E. Giant Intracanalicular Fibroadenoma of the Breast. Arch Surg 43: 588 (Oct.) 1941

Cooper, W G, Jr., and Ackerman, L V. Cystosarcoma Phylloides, Surg, Gynec. & Obst 77: 279, 1943

Geschickter, C F. Giant Mammary Myxoma, in Diseases of the Breast, Philadelphia, J B Lippincott Company, 1945, p 319

masses are made up of myxomatous connective tissue in polypoid fibrous structures covered by cuboidal epithelium as seen under the microscope. There is a definite incidence of sarcoma in this group. The differentiation between giant myxoma and fibrosarcoma is not easy and requires careful microscopic study and experience in some cases. If sarcomatous



Fig. 6.—Photograph of a benign fibroadenoma and cross section of the breast.

change is found, amputation of the breast including the pectoral fascia, without axillary dissection, is indicated. The lesions do not as a rule metastasize to regional lymph nodes. Wide local excision is indicated for the benign lesions.

Benign Intracystic Papilloma.—Benign intracystic papilloma includes (1) papillary invaginations of the larger ducts, (2) intracystic papillomas and (3) papillary hyperplasia which occurs in adenosis of the breast. The condition with the exception of papillary changes seen



Fig. 7.—Intracanalicular myxoma. Photomicrographs showing periductal proliferation of fibrous stroma and polypoid, myxomatous fibrous structures covered with cuboidal epithelium.

in patients with adenosis of the breast, occurs usually in women near, at or beyond the menopause. It occurs with equal frequency in nulliparous and in parous women.

The tumors vary from 1 to several centimeters in size. They occur in the central zone of the breast and are frequently associated with a sanguineous discharge from the nipple. Evidence of a lump may have existed for from six months to five years. The mass is soft, compressible and usually freely movable, is shown on transillumination to be an opaque area and causes bloody discharge from the nipple when compressed. The tumor has at times been referred to as a low grade papillary or duct cancer.

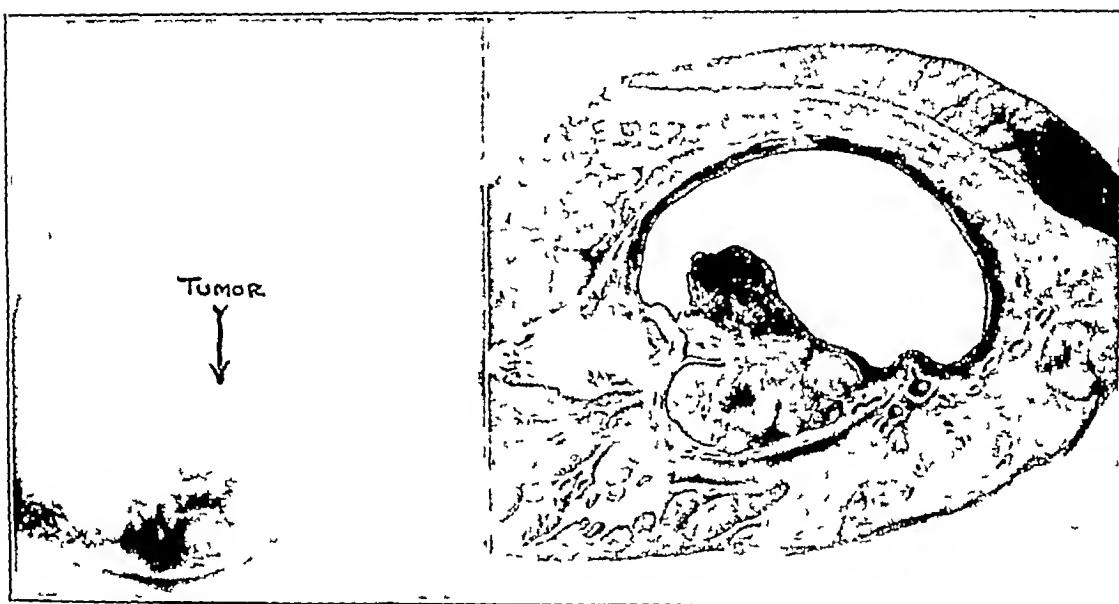


Fig. 8.—Benign intracystic papilloma. Clinical appearance of breast and cross section of a specimen.

The tumors are best treated by excision. They should be excised along with a zone of surrounding breast tissue. The wall of the cyst at the base of the papilloma must be examined under the microscope. If infiltration of the process occurs into or beyond the cyst wall or if malignant changes are noted in the papilloma, radical mastectomy should be performed.

The benign tumors on excision are found to be encapsulated (figs. 8 and 9). The papillary lesion may completely fill the cyst cavity. The cavity may be multilocular and filled with small papillomas. The papilloma is composed of branching tuftlike stalks festooned with

epithelial covering. The central stalk carries the blood supply and is the only attachment of the papilloma to the cyst wall. The epithelium over the fibrous core is in orderly arrangement and usually two layers thick. The outer layer is composed of tall columnar cells.

Tumors over 5 cm. in diameter frequently show malignant changes.



Fig. 9.—Benign intracystic papilloma. Photomicrograph showing stalk of papilloma.

In adenosis of the breast, papillary hyperplasia is common in women between the ages of 30 and the early forties. Both breasts are usually affected, and the lesions are toward the periphery.

The breasts are usually small and unequal in size. Multiple pea-sized nodules are felt in one or both breasts. Bloody discharge from the nipple may occur in 4 per cent of the cases.

The tumors are usually noted to fluctuate frequently in size at first. Pain accompanies the formation of tumor in about half the cases.

Because of the fact that papillary hyperplasia is widely distributed in the breast or breasts in adenosis, the site of the exploratory incision is chosen with great difficulty. This is especially true in the presence of blood from the nipple. The duct or area can usually be located by transillumination or palpation to observe the place from which the blood can be expressed. The questionable areas must be explored and the affected zone excised. The tissue must be examined histologically, as cancer may be a definite possibility. Microscopically the lobule buds of the terminal tubules show cystadenomatous change, namely, epithelial proliferation in dilated terminal tubules. Some of the cystic tubules seem completely filled.

Adair¹² stated that bleeding of the nipple occurs about as often in benign conditions of the breast (57 cases) as in malignant conditions (51 cases).

Geschickter,¹³ in studying the over-all picture of the bleeding nipple, found that it occurred in only 4 per cent of all instances of cancer of the female breast. This symptom preceded the appearance of a breast tumor in only 22 of 100 instances of benign lesions studied. He concluded, however, that any bleeding from the nipple must be carefully studied and the cause eradicated because potentially benign papillomas may become malignant.

An intriguing endocrine origin for intracystic papillomas has been suggested by Geschickter,¹³ based on these three factors (1) the presence of epithelial buds which are remnants of normal mammary development, (2) their distribution along the large ducts or at the terminal tubules, and (3) prolonged regenerative activity in the buds. Usually the last factor occurs at the menopause or after prolonged estrogen stimulation. This estrogenic stimulation must be constant and prolonged but not necessarily of high intensity. In experiments on female rats, begun at birth, the mammary gland was constantly stimulated with estrone pellets after seventy days of injections of 25 gamma of estrone in oil twice daily. The author found that fibroadenomas occurred in one hundred and thirty to one hundred and ninety days but that papillomas appeared only after three hundred and fifty to five hundred and fifteen days.

12 Adair, F. E. Sanguineous Discharge from the Nipple and Its Significance in Relation to Cancer of the Breast, *Ann Surg* **91** 197, 1930.

13 Geschickter, C. F. Bleeding from the Nipple and Benign Intracystic Papilloma, in *Diseases of the Breast*, Philadelphia, W. B. Saunders Company, 1945, p. 325.

Endocrine therapy for this group of tumors does not seem warranted and indeed may be hazardous in view of the endocrine factors involved in the formation of the lesions, which may be followed even by the production of cancer

SUMMARY

Mammary dysplasia and benign neoplasia have been presented with reference to the clinical aspects of the diseases involved

The endocrine aspects of the various entities have been emphasized
Treatment has been discussed including endocrine therapy

It is hoped that this presentation will stimulate further consideration of the cause and treatment of this group of diseases of the breast

SURVEY OF INTESTINAL OBSTRUCTION

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THE INTRODUCTION of the use of indwelling gastric and intestinal siphonage by Wangensteen¹ and the use of intravenously administered fluids and plasma and blood replacement as well as of other therapeutic and diagnostic aids, particularly the antibiotics and roentgen examinations, have allayed some of the dread of acute intestinal obstruction.

Many physicians are now reasonably sure of themselves as regards the differential diagnosis between strangulating and simple obstructions and the technical management of affected patients. The mortality, however, remains much too high.

An attempt has been made to survey the management in the last five years of acute intestinal obstruction occurring at the Los Angeles General Hospital. It was not the purpose of the study to go into detailed clinical and laboratory findings but rather to search for possible pitfalls of omission or commission as well as for surgical blunders and, in reflection, to see if one might not do differently if again faced with a similar situation and thereby possibly save lives.

The survey shows a mortality rate comparable with that found in similar institutions handling a large number of acute surgical emergencies in spite of the fact that in Southern California there is the additional problem of the presence of aged people who have been inherited from other states and who, aside from intestinal obstruction, are in poor physical condition. In 1940 McKittrick and Sarris,² of the Massachusetts General Hospital, reported a mortality of 18 per cent among 124 patients operated on. In July 1946 Calihan and his associates,³ of the Johns Hopkins Hospital, presented a ten year survey of 204 cases of surgical obstruction including cases of simple obstruction, volvulus, internal hernia and intussusception, a mortality of 20 per cent was

Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec 6, 1946

1 Wangensteen, O H Intestinal Obstruction, Springfield, Ill., Charles C Thomas, Publisher, 1945, pp 6-7

2 McKittrick, L S, and Sarris, S P Acute Mechanical Obstruction of the Small Bowel Its Diagnosis and Treatment, New England J Med 222 611-622 (April 11) 1940

3 Calihan, R J, Kennedy, J D., and Blain, A, III Intestinal Obstruction Study of Two Hundred and Four Acute Cases with Reference to Possible Efficiency of Antibacterial Therapy, Bull Johns Hopkins Hosp 79 21-33 (July) 1946

reported. In an identical group of 309 surgically treated patients the mortality was 21 per cent. In 1945 Griffin, Bartron, and Meyer,⁴ of the Cook County Hospital, reported a mortality of 40 per cent in volvulus of the sigmoid associated with operative and nonoperative procedures. A similar mortality was reported by Dennis,⁵ of the University of Minnesota Hospital. In our own series of volvulus of the sigmoid the mortality is 37.5 per cent.

During five years, 1941 to 1945 inclusive, 11,590 major operations were done in general surgical cases at the Los Angeles General Hospital. This is exclusive of operations in the other surgical specialties such as orthopedic, neurosurgical or gynecologic operations. During this time, surgical treatment was carried out in 1,107 proved cases of acute intestinal obstruction. Cases of ileus, peritonitis and possible or partial obstruction are not included in this group.

CLASSIFICATION

The classification of the different types of acute intestinal obstruction encountered is shown in table 1.

TABLE 1.—*Incidence of Acute Intestinal Obstruction at the Los Angeles General Hospital, 1941 to 1945*

Obstruction by bands and adhesions	359
Early postoperative	31
Late postoperative	274
Without previous surgical treatment	54
Strangulated external hernia	292
Volvulus	72
Large bowel	27
Small bowel	45
Carcinoma of colon	105
Sigmoid and descending colon	90
Splenic flexure	9
Transverse	6
Hepatic flexure	9
Cecum and ascending colon	11
Carcinoma of rectum	27
Diverticulitis	24
Intussusception	39
Strangulated internal hernia	11
Mesenteric thrombosis	38
Congenital anomalies	32
Imperforate anus	13
Congenital atresia	7
Megacolon	4
Meckel's diverticulum	8
Gallstone or foreign body	7
Endometriosis	2
Regional ileitis	4
Extrinsic tumor	5
Primary tumor of the small bowel	3
Metastases terminal	51
Obstruction from superior mesenteric artery	2
Tuberculosis of the cecum and peritoneum	5
Radiation obstruction	1
Stricture of the rectum	5
Trauma	3
Total	1 107

4 Griffin, W D , Bartron, G R , and Meyer, K A Volvulus of the Sigmoid Colon Report of Twenty-Five Cases, Surg , Gynec & Obst **81** 287-294 (Sept) 1945

5 Dennis, C Treatment of Large Bowel Obstruction Transverse Colostomy , Incidence of Incompetency of Ileocaecal Valve, Experience at University of Minnesota Hospitals, Surgery **15** 713-734 (May) 1944

Because of limitation of time and space, the paper will be limited to that part of the survey covering bands and adhesions, volvulus and strangulated external hernia.

BANDS AND ADHESIONS

Cases of obstruction by bands and adhesions were grouped according to whether the obstruction was early postoperative or late postoperative, the former occurring during the first month after abdominal operation.

Early Postoperative Obstruction—There were 31 patients for whom the diagnosis of early postoperative obstruction was made. There were, no doubt, more similarly affected, but because of the policy of the hospital of intubating immediately in all suspected cases as well as in all cases of acute abdominal conditions requiring surgical treatment, the

TABLE 2.—*Surgical Procedures in Late Postoperative Obstruction by Bands and Adhesions at the Los Angeles General Hospital, 1941 to 1945*

Number in whom surgical procedures were carried out for late postoperative obstruction by bands and adhesions	328
Total number treated surgically	189
Adhesions released (mortality 5.4%)	146
Resections (mortality, 28.7%)	24
Enterostomy	5
Perforation closed	4
Enteroenterostomy	4
Cecostomy	3
Invagination of the necrotic area	1
Closure of the fecal fistula	1
Plication to prevent recurrence (mortality 36.8%)	1
Average surgical mortality	11.1%

number has been held rather low. Ten patients were reoperated on, 3 of whom died.

Possibly in at least 1 case it was inadvertent to reoperate, as in the search for adhesions an abscess was encountered, with resultant soiling and fatal peritonitis. Inflammatory reaction in the vicinity had accounted for the obstruction. That few such cases are found in this category is ample proof that our surgical staff is mindful of the fact that obstruction due to inflammatory processes will as a general rule respond to suction siphonage.

Late Postoperative Obstruction—Cases of late postoperative obstruction by bands and adhesions constitute a large proportion of the total cases of intestinal obstructions. In this survey it was found in 328 patients, 274 of these had previous surgical treatment, and for 54 either it was specifically stated that there had been no previous operation or nothing could be found in the history or physical examination which indicated a previous operation.

Obstruction by adhesive bands is indeed no respector of age. The youngest patient was 4 days old and the oldest 86 years. Thirty patients were above 70 years of age, and 72 were above 60. There were 139 treated by suction only, and 189 were operated on. Table 2 shows the operative procedures and the mortality.

Simple Versus Strangulating Obstruction.—As I studied the histories, I was soon convinced of two facts. 1. The duration of the obstruction had nothing whatsoever to do with the degree of obstruction present. A twelve hour obstruction was often gangrenous while a three day obstruction might be perfectly harmless. 2. The differential diagnosis between an early strangulating lesion and a simple obstruction, made on the presence or absence of tenderness as described by Wangenstein, was not so easily established.

McKittrick and Sarris stated in their report that they were unable to make this early differential diagnosis. Calihan and others, in their survey of July 1946, stated

In the papers by some of the proponents of conservative therapy who claim to be able to differentiate strangulation there can be found incidents where strangulation had been temporized with disastrous results. The burden of responsibility therefore rests on the surgeon who attempts to make this early differentiation and finds after an interval of conservative therapy that his patient has a strangulated obstruction.

Among the patients covered by this survey 8 deaths in the group with obstruction by bands and adhesions could possibly be attributed to delay and failure in recognizing the strangulating lesion. The 8 patients who died were treated with siphonage for from two to seven days before surgical intervention. Four additional patients who lived might possibly have been spared a resection had surgical intervention not been delayed because of the calming influence of the Miller-Abbott tube.

Strangulation occurred in 32 per cent of McKittrick's 136 cases, and in Dixon's group of 166 patients at the Mayo Clinic 26 per cent were strangulated.⁶ This is a high percentage, and one might well ponder before glibly slipping in a nasal tube with the idea that that will take care of things for the next twenty-four hours.

Pitfalls in Management.—In looking for pitfalls in management, it was not felt that preoperative suction and fluid replacement, which were carried out in all patients without exception, could be criticized. Blood or plasma, or both, was given in about 60 per cent before or during the surgical procedure. I consider this to be an average percentage, but it

⁶ Schlicke, C P., Bargen, J A., and Dixon, C F. Management of Intestinal Obstruction. Evaluation of Conservative Therapy, J. A. M. A. 115:1411-1416 (Oct. 26) 1940.

should be given in all, since Collier⁷ has shown that the loss of blood and plasma is usually greater than it appears to be on the surface. For 2 patients who went into shock on the operating table no record was found of blood or plasma having been given.

In looking for technical errors I found the following. The youngest patient, 4 days old, was examined, and a diagnosis was made of intestinal obstruction due to the presence of meconium. The abdomen was apparently thoroughly explored, but at autopsy a single violin band of adhesions was found completely obstructing the upper part of the ileum.

There was 1 case in which a cecostomy was performed for obstruction of the small bowel. This is a surgical blunder, and one might wonder what went through the surgeon's mind. It happened in this manner. There was great distention, and a flat plate roentgenogram of the abdomen revealed what the surgeon interpreted as a dilated large bowel. The cecostomy was done in the belief that there was an obstruction at the sigmoid.

This brings up the matter of the interpretation of the flat plate roentgenogram. It is not always easy to differentiate between the small and the large bowel under considerable tension. Many of these emergencies happen at night. It would be a great help if a roentgenologist were on call to interpret properly and to report on a roentgenogram after a barium enema when indicated. So far, however, I do not know of a single hospital in which the department of roentgenology is anxious to share this idea with the surgeon.

In 1 patient a loop of intestine was caught between the lateral wall and a colostomy opening performed at the sigmoid elsewhere. This could have been avoided if the surgeon had closed the gutter when performing the colostomy.

There were three possibly avoidable technical errors in which perforation and soiling occurred during the exploration of distended loops of intestine to find the obstruction. Aspiration to deflate by one of the methods described by Wangensteen⁸ might have prevented this. To perform an aseptic anastomosis after such soiling as was done in the cases concerned is obviously incongruous.

This brings up the problem of aseptic anastomosis. In eight resections the surgeon definitely dictated an aseptic type and in ten an open type of anastomosis. Of the 10 patients in whom open resection was performed, only 1 died, while of the 8 in whom aseptic anastomosis was done, 3 died. In these 3 the perforations just mentioned occurred.

⁷ Collier, F. A., and Maddock, W. G. Water and Electrolyte Balance, Surg., Gynec & Obst. 70: 340-354 (Feb. no. 2A) 1940.

so no conclusions can be drawn from this. It is hoped that the discussions will bring out some sharp opinions on this matter. Wangensteen is of the opinion that aseptic anastomosis is of paramount importance, but we believe that this opinion is not universally shared.

The toxicity of the contents of the obstructed intestine is still debated. The value of penicillin has, however, been demonstrated by Blain and Kennedy, of the Johns Hopkins Hospital.⁸ They were able to prolong the lives of dogs with strangulating obstruction and demonstrated that resection could be done in such dogs at a period which was twice the survival time of control dogs not treated with penicillin. It is hoped that the immediate administration of massive doses to all patients, entering the hospital with intestinal obstruction will materially lower the mortality rate, though penicillin should not be used as another adjuvant with which to temporize in the treatment of this disorder.

Patients who are repeatedly returning to the hospital with acute intestinal obstruction present a real problem. I know of 2 patients who have been admitted on occasions too numerous to mention. One of them, a nurse, had been admitted thirty times. Most patients are best treated by suction, but there again there is a pitfall. One patient was admitted five times and relieved by suction. On the sixth admission he was again treated with siphonage, but this time he had a strangulating lesion, which was not recognized early. Enterostomy was performed but he died.

In this survey I found that 81 patients had had previous surgical treatment for obstruction and 41 had had previous suction. About one half of these had both. It is with such patients that one should be doubly cautious. It is so easy to look up the past history and note that they were previously relieved by suction and then to resume siphonage only to find that because of temporization a strangulating lesion has developed.

The folly of meticulously separating massive adhesions is well known. The method of plicating intestine as described by Noble has been resorted to on a few occasions. I have formed no conclusions on this procedure and trust that some one will enlighten me. It appears that, if not too extensive, resection of the matted coils would still be preferable, the resection should be done at a quiescent stage between the flare-ups of acute intestinal obstruction.

8. Blain, A., III, and Kennedy, J. D. Effect of Penicillin on Experimental Intestinal Obstruction. Studies on Strangulated Low Ileal Obstruction, Bull. Johns Hopkins Hosp. 79: 1-20 (July) 1946.

The experimental use of intraperitoneally administered heparin has recently been tried by Lehman⁹ in the hope of preventing adhesions. The contraindication for its use is a bleeding raw surface. Unfortunately, it is in the presence of this that one would consider it a godsend to have something which could prevent adhesions. The use of heparin therefore seems of doubtful value.

SUMMARY

A survey has been made of the occurrence in the last five years of acute intestinal obstruction at the Los Angeles General Hospital.

The mortality of this condition there as elsewhere remains too high.

Delay in recognizing a strangulating lesion and technical errors constitute the major factors in keeping the mortality rate high. Technical errors are too frequent. Delay is due in no small part to the calming influence of indwelling siphonage both on the patient and on the surgeon, who before the advent of suction had a more wholesome respect for acute intestinal obstruction than he has now.

It is worth repeating that the differentiation between a simple lesion and an early strangulating one is not necessarily easy. Operation may be avoided in a fair number of patients, but it is of greatest importance that it be withheld even temporarily only in cases in which there is no question whatsoever of strangulation of the bowel.

As the threshold of shock in a patient with acute intestinal obstruction is low, we believe that no patient should be allowed to have surgical treatment without having first received blood or plasma or both.

The recent experimental work at the Johns Hopkins Hospital in the early use of massive doses of penicillin is promising.

It is urged that the surgical sections and the departments of roentgenology of hospitals have a yearly intensive review of all types of intestinal obstruction. In this manner, certain pitfalls of diagnosis and management would be brought to light, and better operative results would be obtained.

DISCUSSION

DR WILLIS D GATCH, Indianapolis I am sorry that I have to discuss this important paper without having studied it before its presentation. I think, however, that I can discuss some points made in it with profit.

Obstruction of the bowel is the most important subject in any consideration of abdominal surgery. Dr Baumgartner's statistics on the causes of such obstruction, if I interpret them correctly, show that about one half of the cases were due to a preceding laparotomy. These studies show that there must be something seriously wrong with abdominal surgery. Peritoneal adhesions are necessary and cannot be prevented. Without them abdominal surgery would be impossible. I,

⁹ Lehman, E P., and Boys, F. Clinical Use of Heparin in the Peritoneum for the Prevention of Adhesions. Report of Fourteen Cases, Arch Surg 43: 933-945 (Dec.) 1941.

therefore, never had much sympathy with research work designed to prevent them, but I believe that any experienced surgeon would say that by the exercise of care, which must include general handling of tissues, the prevention of drying of the peritoneal surfaces, the sparing use of gauze packs and the intelligent use of omentum, the formation of dangerous adhesions can be prevented in most cases.

Several important discoveries on obstruction deserve discussion. First of these is that distention of the intestines is due practically entirely to swallowed air and that distention can be entirely prevented by the use of the Levine tube and continuous gastric suction. Dr. Singleton keeps up gastric suction for some time after every laparotomy. I use it whenever signs of gastric distention begin to appear. The second is that no case of obstruction of the bowel is an emergency. I heard a discussion of such obstruction years ago in this society, in which member after member would get up and emphasize the emergency nature of every case of such obstruction. They subscribed to the dictum, "Never let the sun go down on a case of obstruction of the bowel." The death rate in those days was 60 to 70 per cent. I think we should now adopt the motto, "Let no case of obstruction of the bowel be considered so urgent as to justify the omission of proper diagnostic study and proper preparation before operation."

Our routine is to take a roentgenogram of the abdomen after administration of barium enema as soon as the patient enters the hospital. This will settle at once whether or not the obstruction is in the large bowel. In case of obstruction of the small bowel, it will also give a good idea as to the site and seriousness of the obstruction.

I differ mildly from Dr. Baumgartner in regard to the diagnosis and proper handling of obstruction complicated by gangrene of the bowel. I agree with him that it is almost impossible to make this diagnosis in many cases. I have many times discovered at operation a loop of gangrenous bowel walled off and apparently doing the patient little harm. Under these conditions, I have found that simple excision of the gangrenous loop with gun barrel enterostomy will save nearly all these patients. We have had, in fact, about 10 consecutive cases without death. The bowel has tremendous powers of protecting itself against gangrene. We have shown that the bowel can endure six hours of total anemia without the patient dying. It is my belief that even when gangrene is suspected it is better to decompress the bowel and get the patient in good condition than it is to operate on him at once. It is extremely dangerous to operate on a dehydrated and starving patient with greatly distended loops of small intestine. In short, I am no longer as terrified by the appearance of a gangrenous loop of bowel as I used to be.

The death rate from the treatment of femoral hernia complicated by gangrenous bowel has not improved in the last seventy years. We have recently treated 3 patients with this condition by a new method. The treatment consists, first, of simple drainage of the femoral sac, second, of decompression of the bowel down to its point of imprisonment in the femoral ring with the Miller-Abbott tube and third, of laparotomy through a low rectus incision, resection of the incarcerated bowel and lateral anastomosis between the ends of the intestine. Two of the patients were obese women between 65 and 70 years of age. The third was a woman of 80 years of age.

The Miller-Abbott tube has done a great deal to lower the death rate in bowel obstruction, but it is often misused. If you insert a Miller-Abbott tube, attach it to the suction apparatus and go away and leave it, you are doomed to disappointment. Once the tube is in the intestine, a nurse should be kept irrigating it con-

stantly and aspirating gas and fluid through it with a piston syringe Under this management it is amazing how rapidly the tube will pass down the intestine

DR. WILLARD BARTLETT JR., St. Louis I had the privilege of reviewing this paper yesterday with Dr. Baumgartner and with Dr. Bern, the head of the Department of Surgery in the University of Southern California, on which service the patients reported on were largely treated

I was struck very much, as they were, with one group of patients, on which Dr. Baumgartner did not have time to detail today, and I am going to call it to your attention because it is the group which challenges their interest most, as it does my own. I am sure few of you go along without seeing such patients in practice. A group of 27 obese patients with incarcerated umbilical hernias were operated on, with a mortality rate of 56 per cent. We have been mistaken with patients like this in the past, and I want to recount some bitter experiences of our own in the management of such patients and the principles we formulated for handling them, which have worked out to our satisfaction since.

Let me speak first of the obese patient with a large ventral hernia in which no incarceration occurs. Such a patient suffers from an increased intra-abdominal pressure. If one attempts to close that very large ring without first having reduced the weight of the patient to approximately the average weight to which his bony structure entitles him, one further increases the intra-abdominal pressure if there is success in getting the ring together. I think it is a fair statement that in 25 to 50 per cent of instances one cannot get the hernial ring closed at all at operation on a patient unprepared by the means I have described.

In patients, however, in whom one congratulates oneself on having got the ring closed under great tension, a characteristic train of symptoms develops immediately because of decrease in vital capacity. They become flushed, their pulse rate rises rapidly after they leave the table, their blood pressure goes up and breathing becomes stertorous. Pulmonary edema and atelectasis develop, and within the first twenty-four hours these patients will take one of two courses. They will get a deep breath in the course of their struggles for breath or during a coughing or vomiting episode and will get immediate relief. Their breathing will become comfortable, their pulse rate will slow down, their temperature will fall and their blood pressure will return to preoperative levels. That is a sign that the entire posterior suture line (at least) has pulled out. If they do not get that relief, however, they will die. The mortality is about 25 per cent, which is too great.

The person who not only is obese and has a large hernial defect but who also has intestinal obstruction has simply doubled the problem of increased abdominal tension due to intestinal distention, and the likelihood of fatal outcome is the more strongly present for such a person. It is not surprising, therefore, that the operative mortality is also doubled for such patients in the essayist's paper.

It has been our plan since the late twenties simply to cut the ring in such patients to allow two things in the first place, one can see whether they have a gangrenous loop at the point of incarceration at the ring, and, in the second place, it permits ready movement back within the abdomen of some of the incarcerated loops, with the relief of incarceration.

The second important point of management at the operating table when one's hand is absolutely forced by the presence of incarcerated bowel which cannot be decompressed by suction is to do an enterostomy at a site remote from the incarceration—not a Witzel enterostomy but a "stab" enterostomy with a Pezzar catheter that does not involve wide opening of the peritoneum.

Thirdly, if the patient has a gangrenous loop (and only the minority of them will at the point of incarceration), that loop should be exteriorized.

DR. THOMAS G. ORR, Kansas City, Kan. When some one discusses mortality rates in intestinal obstruction, I immediately want to know what he is talking about. One of the slides showed that 131 patients were treated without operation, with a mortality of 45 per cent. Were these really cases of intestinal obstruction? I believe that we should confine our definition of intestinal obstruction to those cases in which the bowel is actually mechanically occluded either with or without strangulation.

When the bowel is functionally obstructed, it of course can be treated without operation successfully in many cases. I believe that such cases should fall in another group and that we should keep the pathologic distinction clear when discussing mortality rates.

It is true that intestinal obstruction may be a difficult diagnosis to make. It may be difficult to distinguish from peritonitis and from paralytic ileus. It is certainly often difficult to differentiate between obstructions due to simple occlusion and those due to strangulation. Strangulated hernias were mentioned as a frequent cause of intestinal obstruction. Young physicians and surgeons should be taught to look for such a cause first when intestinal obstruction is suspected. I can now recall 2 patients who were treated by internists for several days before being sent to a hospital. Both of these patients died after late operations. In my experience internists more frequently miss the diagnosis of strangulated hernia than do surgeons.

DR. ARTHUR B. McGRAW, Grosse Pointe, Mich. I should like to ask Dr. Baumgartner to tell us the distribution of the different types of anesthesia in these operations which he has been reporting. I believe that it is fair to say that in operating for intestinal obstruction the factors which make the outcome of the operation unpredictable are the length of time the intestines are exposed and the amount of manipulation which is necessary in order to determine and deal with the site of obstruction. The kind of anesthesia used and the relaxation obtained thereby influence these factors of time and manipulative trauma and also influence the matter of whether there is inadvertent or necessary exteriorization of large amounts of the small bowel during operation.

During the past year, we have had at our hospital the services of a young and expert anesthesiologist, and he has gone far toward making us enthusiastic over the merits of gas anesthesia supplemented by curare in difficult abdominal surgery. In many cases of acute intestinal obstruction there are good reasons for not giving spinal anesthesia in spite of the relaxation obtained thereby.

I simply want to bear testimony to the help we have had with gas anesthesia and curare in handling some of our cases of intestinal obstruction.

DR. CONRAD J. BAUMGARTNER. I think we might have misled Dr. Bartlett a little bit in the slide which showed a 58 per cent mortality in umbilical hernia. That percentage was not an operative mortality but was the average mortality among all patients who entered the hospital with a diagnosis of strangulated umbilical hernia. It was included purely to show the lethal effect of umbilical hernia. I do not know offhand how many were moribund on admission. Some hernias were treated conservatively, including one or two umbilical hernias. There were a few cases in which strangulated femoral hernia had been actually missed.

As to Dr. Orr's question about those patients who were not operated on—there is a chance that we are likely to have made errors, but I will say that I went over

personally (along with the residents) the histories of more than 2,000 cases in which the diagnosis was intestinal obstruction. We eliminated those patients who we thought had ileus or peritonitis or adynamic ileus and accepted those who we felt had definite simple obstructions. Not all patients who get well from simple obstruction have just ileus, because we also happen to know that some of these patients were treated five or six times with suction and on the sixth time they had a strangulating lesion. So they did not have adynamic ileus the first time, but they had a simple obstruction then and later on a strangulating lesion.

You cannot make the flat statement that everybody who gets well without surgical treatment had an adynamic ileus and not a simple obstruction. Of course, we may have been in error in some. There is no way of telling, and likely some of those whom we accepted had not simple obstructions. But after reviewing each history and all the findings that went along with it, we accepted them. We discarded almost 1,000 cases diagnosed as examples of simple obstruction because we didn't think the diagnosis was correct.

Dr McGraw asked about the type of anesthesia. Although our studies to date are not complete, it is my impression that spinal anesthesia was used in at least 90 per cent of the cases.

PLEUROPULMONARY MANIFESTATIONS OF AMEBIASIS

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DURING the past year, we have seen on the thoracic surgery service at Hines 10 cases of amebiasis. These came to our service only because their principal complaints or findings were referable to the chest. It is the purpose of this paper to call attention to the considerable amount of amebiasis now being seen and to point out that this amebiasis may appear in bizarre forms simulating common lesions of the chest. A survey of the literature of recent years has disclosed only a few scattered articles by authors in such endemic areas as India, Africa, Australia, and Brazil reporting single cases of pleuropulmonary amebiasis. In 1938 Keeton and Hood¹ at the University of Illinois reported 5 cases collected by them over a three year period. In 1936 Ochsner and DeBakey² reported a series of cases in New Orleans.

Of the 10 patients seen by us, 4 were admitted directly to our service, 2 were transferred from the medical service, and 4 were seen in consultation on the medical service. The preliminary or admitting diagnoses based on a brief history and examination were as follows: in 4 cases, pneumonia, in 2, empyema, and in 1 each, pulmonary abscess, appendicitis, peptic ulcer and cholecystitis. Six representative cases will be briefly described at this time with reproductions of their roentgenograms before us.

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This article is an abstract of a paper presented at the fourth annual meeting of the Central Surgical Society, Feb 20, 1947 at the Veterans' Administration Hospital, Hines, Ill.

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1 Keeton, R. W., and Hood, M. Symposium on Pneumonia Pulmonary Disease Secondary to Amebiasis, *M Clin North America* **22** 27-43 (Jan) 1938

2. Ochsner, A., and DeBakey, M. Pleuropulmonary Complications of Amebiasis Analysis of One Hundred and Fifty-Three Collected and Fifteen Personal Cases, *J Thoracic Surg* **5** 225-258 (Feb) 1936

REPORT OF CASES

CASE 1—This patient was admitted seriously ill with fever, cough, dyspnea, pain in the right side of the chest of six days' duration and diarrhea of three days' duration. He was slightly jaundiced and showed physical signs of effusion at the base of the right lung. His liver was palpable 4 cm below the right costal margin but was not tender. A bedside roentgenogram of the chest showed elevation of the right side of the diaphragm and evidence of pleuritis at the base of the right lung. A history of service in the South Pacific with recurrent, mild attacks of diarrhea, combined with his present symptoms, suggested amebiasis with ruptured hepatic abscess. Specific therapy was temporarily withheld while attempts were made to isolate amebas in the stools. However, the patient's condition rapidly deteriorated, and although administration of emetine hydrochloride was started on the fifth day,

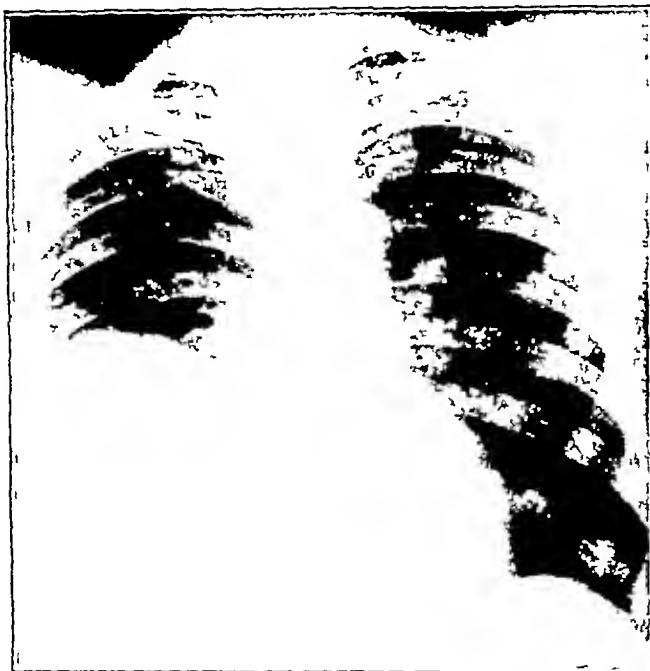


Fig 1 (case 2)—Marked elevation of right side of diaphragm with relatively clear costophrenic angle.

he died on his seventh day in the hospital. Autopsy showed extensive amebic ulceration of the colon and ruptured hepatic abscess with subphrenic abscess.

CASE 2—The patient had had chills, fever, cough and pain in the right side of the chest of increasing severity for three weeks prior to admission and his disease was diagnosed as pneumonia. He showed no improvement on penicillin therapy and in a few days began to expectorate large quantities of "catsup-like sputum." Ruptured subphrenic abscess with bronchial fistula was recognized, and he was transferred to our service, where immediate open drainage of the right anterior subphrenic space was instituted. He showed rapid improvement following drainage, and the cough and expectoration soon disappeared. The sputum showed an organism suggestive of ameba, and a course of emetine hydrochloride was given.

as were also found after many examinations of the pus from the subphrenic abscess. After emetine therapy, drainage almost stopped but later increased in amount, it was finally completely checked by administration of a second course of emetine hydrochloride followed by chiniofon.

CASE 3.—This man was transferred to us from another veterans' hospital with a diagnosis of probable pulmonary abscess. His symptoms dated back approximately seven months. On arrival here, he was emaciated and seriously ill, and expectorated about a quart (0.94 liter) of "catsup-like sputum" daily. Regular roentgenograms of the chest showed no obvious source of this sputum, nor was the pneumogram helpful in demonstrating any pathologic condition. A diagnostic laparoperitoneum was performed, demonstrating obliteration of the subphrenic area anteromedially. Although no amebas could be found in the sputum, a course

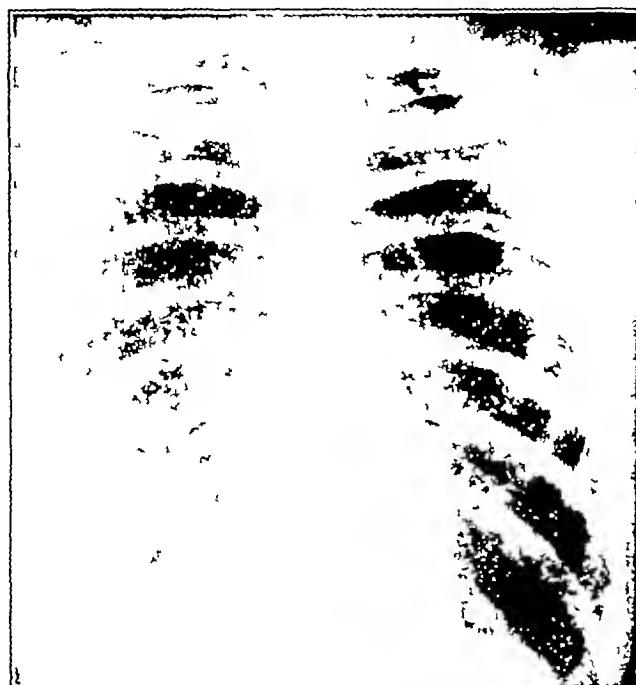


Fig. 2 (case 4).—A large round mass is seen in the lower pulmonary field on the right, and on lateral view is found to be posterior and separated from the diaphragm by a thin layer of aerated lung.

of emetine hydrochloride was given, followed by rapid improvement of symptoms and cessation of expectoration. The patient was soon discharged well.

CASE 4.—This patient, also a South Pacific veteran, had an attack of cough, expectoration, night sweats, hemoptysis and loss of weight early in 1946, and his condition was diagnosed by his private physician as virus pneumonia. He improved and returned to work, but in September the same symptoms returned and he was admitted to the Veterans' Administration Hospital at Hines. A roentgenogram taken in January 1946 showed only a moderate elevation of the right side of the diaphragm. Roentgenograms taken on his admission in September showed a round mass in the right lower posterior pulmonary field which could be interpreted as

abscess, tumor or possibly tuberculoma. Bronchograms showed only a space-occupying lesion in this area. On suspicion, emetine hydrochloride was given, and in a period of less than six weeks the lesion completely disappeared. A pneumoperitoneum showed a clear right subphrenic space. Sputum and stools were all negative for amebas. The patient was discharged well.

CASE 5—This patient had the typical, acute pneumonia picture of chills, fever, cough and vomiting. Sulfadiazine and penicillin had little effect on his symptoms, and after two weeks he began to expectorate copious amounts of "anchovy-sauce" sputum. Amebiasis was then suspected, and a course of emetine hydrochloride was administered, followed by prompt relief of symptoms and the disappearance

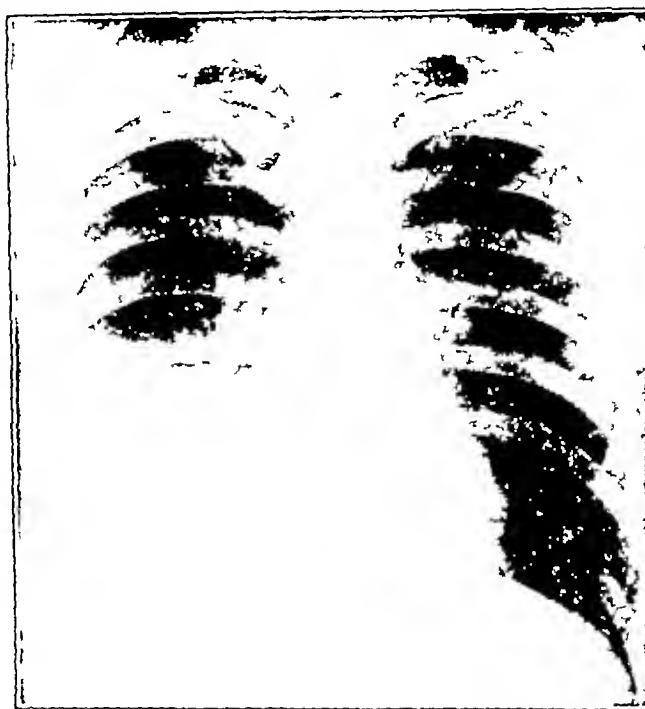


Fig. 3 (case 5).—There is partial obliteration of lower third of right pulmonary field. The diaphragm was not definitely visualized, but was thought to be fixed on fluoroscopic examination.

of the cough and expectoration. No amebas were found in the sputum, but a specimen of stool contained amebas.

CASE 6—This young South Pacific veteran had an attack of pain in the right shoulder, followed in a few days by anorexia, pain in the lower part of the chest and the upper part of the abdomen on the right side and general malaise. He gradually became short of breath and showed increasing fever. His physician diagnosed empyema, aspirated about 1,000 cc. of bloody fluid from the right side of his chest and then advised hospitalization. A roentgenogram on admission, one month after onset of symptoms, showed the diaphragm high on the right side and a clear pulmonary field above, indicating that the aspirated fluid had come from the subphrenic space rather than the pleural cavity. Aspiration was performed here

on several occasions with air replacement, thus demonstrating a huge subphrenic space and apparently marked hepatic destruction. Roentgenograms showed two large subphrenic cavities with fluid levels, and a roentgenogram taken in the left decubitus position helped further to outline the extent of these cavities. Amebas could not be found in the aspirated fluid, but a course of emetine hydrochloride was given, this was followed by immediate relief of symptoms and return of temperature to normal. The subphrenic cavities were gradually becoming obliterated, but before final results could be evaluated, the patient, feeling well, left the hospital and failed to return for check-up.



Fig. 4 (case 6).—The right side of the diaphragm is very high. Bloody fluid (1,500 cc.) has been aspirated from the subphrenic space and partially replaced by air. Note two separate fluid levels.

COMMENT

It is obvious from review of these cases that no typical picture or syndrome can be described. About the only common finding in all cases is roentgen evidence of elevation of the right side of the diaphragm. History of previous significant dysentery was unusual, but a period of service in North Africa or the South Pacific was in the record of all but 2. Demonstration of amebas in the sputum, stool or aspirated fluid was made in less than half of the patients. These cases have clearly shown that an amebic abscess can rupture into the subphrenic space, perforate the muscular barrier of the diaphragm and even rupture into a bronchus without causing either general peritonitis or empyema.

SUMMARY

The following points may be stressed. Amebiasis is being seen fairly frequently, especially in veterans of the North African or South Pacific theaters. Some of these cases of amebiasis may present findings typical of common diseases of the chest. After a reasonable effort is made to rule out the common lesions of the chest in such cases, one should suspect amebiasis and start specific treatment without further delay. Demonstration of the amebas is frequently impossible, and diagnosis must be based on favorable response to emetine hydrochloride therapy. The treatment of choice is a course of emetine hydrochloride, repeated if necessary, and supplemented by an orally administered amebicide and by aspiration if indicated to relieve symptoms of pressure. Early surgical drainage is not indicated and, in fact, may serve to delay recovery.

SOME PHYSIOLOGIC AND BIOCHEMICAL ALTERATIONS INCIDENT TO SURGICAL INTERVENTION

Report of a Case

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THE SURGEON is often presented with a deranged metabolism in patients who have undergone surgical treatment. The derangement may be due to the damaging effects of the operation itself or to a combination of the basic disease process, the operation and other complicating factors such as starvation or salt imbalance. Although knowledge of the metabolic disturbances which take place after operative procedures is admittedly highly important, the literature on this subject is fragmentary and incomplete. As a rule, only a few aspects of the physiologic process in the patient have been studied, such as organic function or tissue electrolytes, and then only in complicated cases. Accordingly, it was felt desirable to make as thorough a study as possible of the physiologic and biochemical changes which take place during and after operation.

The selection of the patient for a composite study of this type was an important consideration. Such a patient should be essentially normal with respect to metabolism and bodily function and should have undergone an operation in which transfusions are usually not absolutely required and yet one in which loss of blood and surgical trauma were substantial. It is important that accurate measurements of loss of blood be made operatively and postoperatively. A consideration of all these factors led us to select a patient subjected to radical mastectomy as the one for study.

The next question to be dealt with was the one of what should be studied. There are limitations in the number of blood specimens which can be removed from a patient without a subsequent transfusion being required. Also, the number of foreign substances used in clinical tests which can be administered simultaneously should be reduced to the minimum because of ignorance of their combined effects in the human

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being. However, the selection of analyses was influenced mostly by the evidence in the literature and by the clinical experiences of surgeons therein. It was felt that a study should be made of the hematologic alterations, changes in body fluid, acid-base metabolism and nitrogen metabolism. The study was organized to provide some information on each of these aspects.

PLAN OF STUDY

All noncoagulated blood was collected in bottles containing dried heparin. All serum specimens were collected under oil. Urine was collected with toluene as the preservative. Blood volume was determined according to the method of Gregerson.¹ All specimens of blood were collected without stasis, and for the hematocrit readings the specimens were centrifuged for at least thirty minutes at 3,000 revolutions per minute.

Preoperatively, determinations were carried out for chlorides,² p_{H} ,³ carbon dioxide content,⁴ total base,⁴ nonprotein nitrogen,⁵ blood urea nitrogen,⁵ total protein⁶ and albumin and globulin.⁵ Hematologic studies included red blood cell counts, hematocrit readings and determinations of the hemoglobin content.⁶ The blood volume¹ and the extracellular fluid volume⁷ were likewise determined. Many of these determinations were repeated two, five and ten hours after the operation and on the first, second and third days postoperatively. Records were kept of the fluid balance, intake of food and loss of blood.

The red blood cell counts were done in triplicate and all chemical analyses done in duplicate.

REPORT OF A CASE

A 56 year old housewife had noticed a lump in her right breast for the past year. One month prior to her admission to the hospital this lump began to enlarge slightly. At the same time her entire breast began to enlarge and appeared inflamed and slightly tender. The patient had otherwise been in good health, and the rest of the history was noncontributory.

¹ Gregerson, M. I. Practical Method for Determination of Blood Volume with Dye T-1824 Survey of Present Basis of Dye-Method and Its Clinical Applications, *J. Lab. & Clin. Med.* **29** 1266-1286 (Dec.) 1944

² Wilson, D. W., and Ball, E. G. A Study of the Estimation of Chloride in Blood and Serum, *J. Biol. Chem.* **79** 221-227 (Sept.) 1928

³ Peter, J. P., and Van Slyke, D. D. Quantitative Clinical Chemistry, Baltimore, Williams & Wilkins Company, 1932, vol. 2

⁴ Gamble, J. L. Chemical Anatomy, Physiology and Pathology of Extracellular Fluid A Lecture Syllabus, Boston, Spaulding-Moss, 1941

⁵ Campbell, W. R., and Hanna, M. I. The Albumins, Globulins and Fibrinogens of Serum and Plasma, *J. Biol. Chem.* **119** 15-33 (June) 1937

⁶ Evelyn, K. A. Stabilized Photoelectric Colorimeter with Light Filters, *J. Biol. Chem.* **115** 63-75 (Aug.) 1936

⁷ Crandall, L. A., Jr., and Anderson, M. X. Estimation of the State of Hydration of the Body by the Amount of Water Available for the Solution of Sodium Thiocyanate, *Am. J. Digest. Dis. & Nutrition* **1** 126-131 (April) 1934

Physical examination revealed a well nourished and well developed white middle-aged woman, weighing 60 Kg, who did not appear ill. The lungs and heart were apparently normal. Her blood pressure was 180 systolic and 70 diastolic. Her right breast in the upper outer quadrant contained a 7 cm rounded hard mass, with its periphery meeting that of the areolar border. The nipple was slightly retracted. The right breast was larger than the left. Several small axillary lymph nodes were palpable.

The results of laboratory examinations, which are in the main discussed elsewhere, were essentially normal. Roentgenograms of the chest and long bones were normal.

A radical mastectomy was performed, without any untoward incident. Her blood pressure at the beginning and conclusion of the operation was 100 systolic and 60 diastolic. Her pulse rate was 100 immediately prior to operation and 80 at the finish of operation. Her respiratory rate remained in the region of 34. An infusion of 1,500 cc of isotonic solution of sodium chloride was given during the surgical procedure. The operative loss of blood was 550 cc.

Except for a pallid appearance, the patient made an uneventful recovery. The wound healed normally. On the first four postoperative days the patient had some nausea and occasionally vomited. The nausea was coincident with the intravenous injection of thiocyanate.

Pathologic examination of the breast and axillary tissue disclosed widely infiltrating scirrhouous carcinoma. A total of thirty diffusely infiltrated lymph nodes were dissected out from the axillary fat.

RESULTS AND COMMENT

The data have been grouped for convenience of discussion into sections on the hemodynamic process, acid-base metabolism, changes in body water and nitrogen metabolism.

The alterations in the hemodynamic process have been illustrated in figure 1. Although there is a considerable reduction in the red cells, hematocrit reading and hemoglobin content from preoperative levels, these values alone do not indicate the full extent of the changes in the composition of the blood. Thus, in spite of a 1,200 cc loss of blood from the operation and the withdrawal of samples over a three day period, the volume is maintained at approximately preoperative levels by a compensating increase in plasma volume. If the blood volume had not been replaced by the increase in plasma volume, the blood count would obviously remain unchanged. Therefore, the reason for the drop in the red blood cell count is hemodilution of the residual blood.

The body can deliver rapidly large amounts of plasma protein to the blood stream after acute hemorrhage,⁸ which accounts for the increase in plasma volume. Even though the plasma protein concentration was observed to fall (see table), total circulating protein remained constant. Since blood hemoglobin cannot be replenished as rapidly as plasma protein, one can understand the precipitous fall in total circulating hemo-

⁸ Madden, S. C., and Whipple, G. H. Plasma Proteins. Their Source, Production and Utilization, Physiol Rev 20:194-217 (April) 1940.

globin and in red cell mass. In any consideration of postoperative anemia it is important, therefore, to follow the changes in the red cell mass and in total circulating hemoglobin, as the red blood cell count alone may be misleading. A low count might therefore signify either an actual lack of the formed elements or an increase in the plasma volume.

Rapid changes in acid-base metabolism were observed as shown in figure 2. The precipitous fall in total carbon dioxide content and the

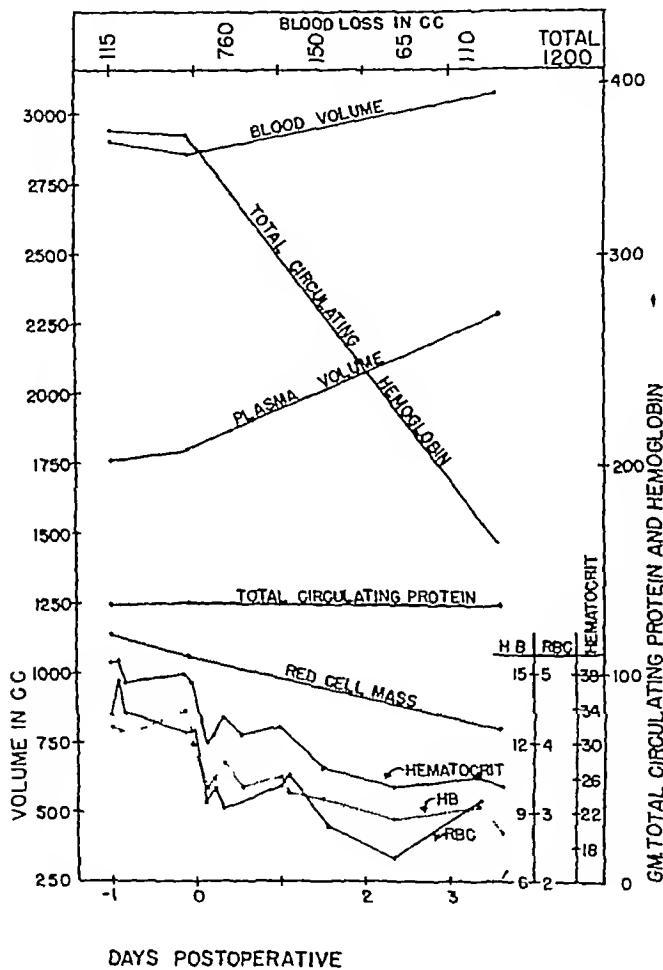


Fig. 1.—Illustration of hemodynamic changes incident to surgical intervention.

shift toward acidity as shown by lower pH values occur without accompanying pronounced changes in total base. These observations are interpreted as the result of an excess of acid, which is probably due to lactic acid which accumulates in hemorrhagic shock. The alterations in chloride content are regarded as compensating for the increase in acid

⁹ Nish, J. Surgical Physiology, Springfield, Ill., Charles C Thomas Publisher, 1946.

present histologic evidence of low grade malignancy they usually progress slowly and usually cause death by interference with pulmonary circulation. Furthermore, they offer an opportunity for surgical removal.

In 2 of the 3 cases of giant primary fibrosarcoma of the pleura described by these authors aspiration was done. One case was discovered incidentally during a routine examination of the chest of a woman being prepared for a gynecologic operation. The large tumor was removed with good recovery. In the second case the tumor was only partially removed because of its size and extensive adhesions. Four years later the patient's symptoms recurred, and the tumor was again partially resected. In the third case the giant tumor gave a clinical history of at least twenty years' duration. Over a period of ten years the patient had been in the hospital five times with a diagnosis of aortic aneurysm and bronchial asthma. Pulmonary edema developed on the fifth admission, the woman died, and the giant tumor was discovered at autopsy.

Cabot Case 18452⁴ (1932) was of a slow growing fibrosarcoma of the pleura. A clinical diagnosis of tumor of the left pleural cavity was established. A thoracotomy was done, but the condition proved inoperable. Death followed four days later, and at autopsy the tumor was estimated to weigh 20 pounds (9,072 Gm.). In this case the clinical history was of five months' duration.

Fawcett⁵ (1945) reported a large fibroma arising from the pleura of the lower lobe of the right lung. A clinical diagnosis of tumor was reached by means of roentgen examination and the finding of numerous endothelial-like cells, many undergoing mitosis in aspirated fluid. At operation the tumor, 12 cm. in diameter, was easily shelled out, and the patient made a good recovery.

In the case of massive primary fibrosarcoma of the pleura recorded in this paper the clinical picture of pulmonary and cardiac embarrassment was caused by pressure of the tumor.

SUMMARY

A case of giant primary fibrosarcoma of the pleura, presenting a clinical picture of pulmonary and cardiac embarrassment, is described. The diagnosis was established at autopsy.

⁴ Incapacitating Dyspnea in an Unusual Chest Case, Cabot Case 18452, New England J Med 207:843-847, 1932.

⁵ Fawcett, A. W. Large Fibroma Arising from Pulmonary Pleura of Right Lower Lobe Brit M J 2:425, 1945.

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CONTROL OF ARTERIAL HEMORRHAGE BY A GELATIN SPONGE "CUFF" AND CHROMIC SURGICAL GUT SHEATH

A New Experimental Method

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THE RECENT experimental and clinical contributions in vascular surgery have stimulated an interest in this field which may lead to further widening of the scope of surgery. The "soluble rod" for arterial anastomosis which was described by Smith¹ was designed to simplify the suture technic which was developed chiefly by Carrel,² Horsley,³ and others, for blood vessel anastomosis. The vitalium tubes which were introduced by Blakemore, Lord and Stefke⁴ for vascular anastomosis and for restoring arterial defects by vein transplants represent a promising technical development in vascular surgery. The absorbable tubes composed of fibrin which were devised by Swenson and Gross⁵ for blood vessel anastomosis represent another important development which overcomes a disadvantage of the vitalium tube in

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Read at the fourth annual meeting of the Central Surgical Association, Chicago Feb 21, 1947

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1 Smith, S. The Soluble Rod as an Aid to Vascular Anastomosis, *Arch Surg* 41:1004 (Oct) 1940, Studies in Experimental Vascular Surgery, *Surgery* 18:627, 1945

2 Carrel, A., and Guthrie, C. C. Uniterminal and Biterminal Venous Transplantations, *Surg, Gynec. Obst.* 2:266, 1906

3 Horsley, I. S. *Surgery of the Blood Vessels*, St Louis, C V Mosby Company, 1915

4 Blakemore, A. H., Lord, J. W., and Stefke, P. L. Restoration of the Blood Flow in Damaged Arteries, *Ann Surg* 117:481, 1943

5 Swenson, O., and Gross, R. E. Absorbable Fibrin Tubes for Vein Anastomoses *Surgery* 22:137 (July) 1947

children's surgery where it would obviously be desirable for the vascular channel to increase in size with the growth of the child. The operation for coarctation of the aorta reported by Gross⁶ and the operation originated by Blalock and Taussig⁷ for malformations of the heart with pulmonary stenosis or atresia and the anastomosis of the aorta to the pulmonary artery developed by Potts, Smith and Gibson⁸ represent most valuable contributions to clinical vascular surgery. These operations were developed as a result of extensive experimental studies on animals in which the technics for these vascular anastomoses were worked out.

The concentration of most of the vascular injuries of the recent war in the hands of a relatively few experienced surgeons has given an impetus to this field of surgery. The reports on the management of vascular injuries, such as the extensive review by DeBakey and Simeone,⁹ indicate that these injuries have been competently handled. However, in only a relatively small proportion of the acute arterial injuries has it been feasible to resort to suture, anastomosis or vein graft with the aid of vitallium tubes. The results in these cases from the standpoint of prevention of gangrene have not been especially satisfactory as compared with the cases in which ligation was done. There is obviously a place for some further study of the problem of repair of a damaged artery which would offer a more satisfactory means of restoring blood flow than having to resort to ligation in so many instances.

In view of the satisfactory results which were obtained in controlling hemorrhage from wounds of the vena cava and other veins in dogs by the gelatin sponge "patch"¹⁰ it appeared plausible to attempt control

6 Gross, R E Technical Consideration in Surgical Therapy Coarctation of Aorta, *Surgery* 20 1, 1946, Surgical Correction for Coarctation of the Aorta, *ibid* 18 673, 1945 Gross, R. E., and Hufnagel, C A Coarctation of Aorta Experimental Studies Regarding Its Surgical Corrections, *New England J Med* 233 287, 1945

7 Blalock, A, and Taussig, H G The Surgical Treatment of Malformations of the Heart in Which There is Pulmonary Stenosis or Pulmonary Atresia, *JAMA* 128 189 (May 19) 1945

8 Potts, W I, Smith, S, and Gibson, S Anastomosis of Aorta to Pulmonary Artery, *JAMA* 132 627 (Nov 16) 1945

9 DeBakey, M E, and Simeone, F A Battle Injuries of the Arteries in World War II, *Ann Surg* 123 534, 1946

10 Jenkins, H P, and Janda, R Studies on the Use of Gelatin Sponge or Foam as a Hemostatic Agent in Experimental Liver Resections and Injuries to Large Veins, *Ann Surg* 124 953, 1946

of arterial hemorrhage with this new hemostatic agent¹¹. A technic was devised which consisted of wrapping a "cuff" of dry compressed gelatin sponge about the wound in the artery and surrounding this with a sheath of chromic surgical gut. With this method, it was possible to control hemorrhage and restore blood flow in wounds of the aorta in experimental animals without having to resort to arterial suture. A preliminary report of this method has been made¹².

EXPERIMENT

A series of 22 dogs were operated on under ether anesthesia and with aseptic technic. The aorta distal to the renal arteries was exposed by a midline or a transverse abdominal incision. The overlying peritoneum was incised and the aorta isolated from surrounding structures. It was necessary in most instances to ligate several of its small branches to permit mobilization. Rubber-covered bulldog clamps were applied above and below the point selected for the wound and then a scalpel was thrust through one or both walls of the vessel (fig 1 A). When the proximal bulldog clamp was temporarily released, the hemorrhage which resulted could best be described as massive (fig 1 B). The gelatin sponge available for these experiments was in the form of sheets approximately 3 inches by 4 inches by $\frac{1}{2}$ inch (7.6 by 10.2 by 1.3 cm). It had been previously heat sterilized and packaged in sealed glass jars by the manufacturer. A piece measuring about $1\frac{1}{2}$ by 2 inches (3.8 by 5.1 cm) was cut from the large sheet. This was then compressed with the fingers until it was pliable and could be rolled into the form of a tube. The gelatin sponge is rather brittle in the dry state and unless it is compressed cannot be rolled up. When moistened, it is more difficult to handle and rather friable. The smaller pieces of gelatin sponge which are commercially available were found to be too narrow and too thin for the purposes of this experiment. The dry compressed sheet of gelatin sponge was then wrapped about the wound in the vessel and held in place with several sutures of extra chromic surgical gut (size 0). The bulldog clamps were then released and the blood flow restored without further hemorrhage (fig 2 A).

The technic described was used in the first five experiments. The gelatin sponge was not found to be strong enough to withstand alone the arterial blood pressure. The technic was then modified by wrapping the gelatin sponge "cuff" in a sheath of chromic surgical gut. This sheath was held in place by several sutures of extra chromic surgical gut (fig 2 B). Some care was necessary in tying up the sutures to avoid constricting the lumen of the vessel and thus impairing the blood

11 Jenkins H P and Clarke, J. Gelatin Sponge: A New Hemostatic Substance. Studies on Absorbability, Arch Surg 51:253 (Nov-Dec) 1945. Jenkins H P, Janda R and Clarke, R. Clinical and Experimental Observations on the Use of Gelatin Sponge or Foam, Surgery 20:124, 1946.

12 Jenkins, H P, Senz, E H, Owen H W and Jampolis, R W. The Present Status of Gelatin Sponge for Control of Hemorrhage, with Experimental Data on Its Use for Wounds of the Great Vessels and the Heart. JAMA 132:614 (Nov 16) 1946.

flow. The subsequent sixteen experiments were then performed by supplementing the gelatin sponge "cuff" by a sheath of chromic surgical gut, except for one experiment, in which a plain surgical gut sheath was used but found to be inadequate for the purpose.

The chromic surgical gut sheath was prepared by two manufacturers¹³ of surgical gut by wrapping the flat strips of sheep intestine, such as are used for



Fig 1-4 scalpel wound of aorta of dog, *B*, hemorrhage from wound of aorta

making ligatures and sutures, about a rod. The rod was removed after the strips had dried, thus forming the sheath. It was necessary to split the sheath along one side so that it could be wrapped about the gelatin sponge cuff. A size was selected which permitted some overlapping of the sheath when the sutures were tied up. The

¹³ Ethicon Suture Laboratories, and Armour Laboratories

chromicizing process was carried out prior to wrapping on the rod by the method customary for the manufacturer. Adequate sterilization for the purposes of these experiments was obtained by immersing in 95 per cent ethyl alcohol for several days. The manufacturers are working out a method of providing this sheath in sealed glass tubes after their usual process of heat sterilization such as is used for ordinary surgical gut.



Fig. 2—*A*, gelatin sponge "cuff" wrapped about wound of aorta while hemorrhage is controlled temporarily by bulldog clamps; *B*, chromic surgical gut sheath which surrounds gelatin sponge "cuff." The sheath is held in place with several surgical gut sutures. The blood flow is restored and the hemorrhage controlled.

At autopsy, the vessel was carefully dissected out and removed. Photographs were taken before and after opening the lumen of the vessel. The specimens were preserved in formaldehyde solution (10 per cent of the U.S.P. concentration), and sections were cut through the wound in the vessel for microscopic study.

RESULTS

All the 22 animals survived the immediate postoperative period. In the series of 5 animals in which the gelatin sponge "cuff" alone was used to control hemorrhage from a wound of the aorta a blowout occurred in 2, which caused death on the fourth and the sixth day respectively from massive retroperitoneal hemorrhage. The other animals in this series died on the second, third and sixth days after operation from distemper and pneumonia. There was no evidence of secondary hemorrhage in these animals, and the lumen of the vessel was found to be patent. However, the gelatin sponge cuff was rather badly fragmented, especially where the sponge was held by the sutures. In one experiment in which the plain surgical gut sheath was used a blowout occurred on the fourteenth day which produced a fatal hemorrhage. In addition, there was a mural thrombus in the region of the wound in the vessel.

In the series of 16 animals in which the gelatin sponge "cuff" was supported by a sheath of chromic surgical gut there was only one blowout from the arterial wound. This occurred on the fourth day. In a second experiment, there was a blowout on the seventeenth day which occurred proximal to the through and through stab wound of the aorta. The wounds in the vessel wall were healed, however, there appeared to be erosion of the vessel where the chromic sheath cut into it at the level of the most proximal chromic surgical gut suture, which was apparently tied up too tight. Six animals died from distemper and pneumonia, or were killed, on the third, the sixth, the ninth, the tenth, the eleventh and the fourteenth day. The sponge "cuff" and sheath were found to be intact, and the lumen of the vessel was patent and free from evidence of thrombosis. The wound of the vessel was easily identified.

Eight animals which survived for longer periods were killed as follows: 2 on the twenty-fourth day and 1 each on the fortieth, the forty-eighth, the fifty-fourth, the sixty-fourth, the seventy-third and the eighty-eighth day. The chromic surgical gut sheath was found to be encapsulated in fibrous tissue which gave additional support to the vessel wall (fig 3A). When this fibrous capsule was opened up, the chromic sheath could be readily identified up to about six weeks (fig 3B). After six weeks to two months, it was difficult to identify the chromic sheath as a separate layer, as it was in a moderately advanced stage of absorption and incorporated in the tissues surrounding the vessel wall, imparting a brown or green color to these tissues (fig 3C). The gelatin sponge could usually be identified grossly in the animals which survived three to six weeks when the vessel was

cut open. The location of the wound in the vessel wall could be detected as a white scar which was apparently well healed over (fig. 4A). In one instance, however, a large propagating thrombus was adherent to the wound in the vessel wall. This thrombus pro-

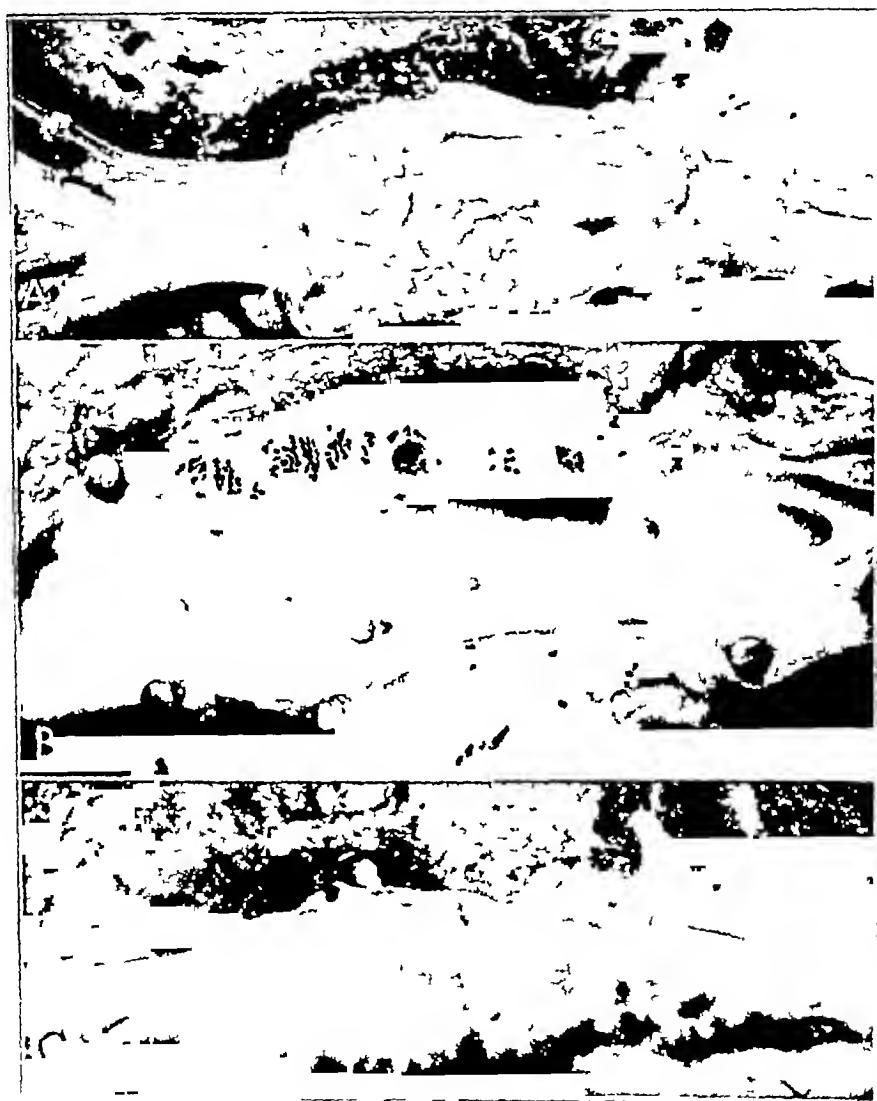


Fig. 3.—*A*, specimen of the aorta twenty-four days after scalpel wound and control of hemorrhage by gelatin sponge 'cuff' supported by chromic surgical gut sheath. The sheath has become encapsulated in fibrous tissue which is continuous with the vessel wall thus providing additional support. *B*, a specimen of the aorta twenty-four days after scalpel wound in vessel wall. The chromic surgical gut sheath can be seen under the partially removed overlying fibrovascular capsule. The wound can be identified as a small depression adjacent to the lumen of a small branch of the aorta. *C*, a specimen of the aorta forty days after repair of scalpel wound by gelatin sponge cuff supported by chromic surgical gut sheath. The sheath has undergone moderate absorption and is incorporated in the fibrovascular tissue surrounding the aorta at this point. There is a dark color imparted to the tissue by the remnants of death.

truded into the lumen but did not occlude it (fig 4 B). There was evidence of aneurysmal dilatation of the vessel wall at the site of injury in one of these specimens. There was induration of the tissues about the sheath in several instances which was not easily explained.

The microscopic studies revealed healing of the wound in the wall of the vessel by scar formation which was covered by a newly formed intima (fig 5). The chromic surgical gut sheath was found to be present in varying stages of absorption. There was a moderate cellular reaction to the surgical gut which varied in intensity in the various sections studied.

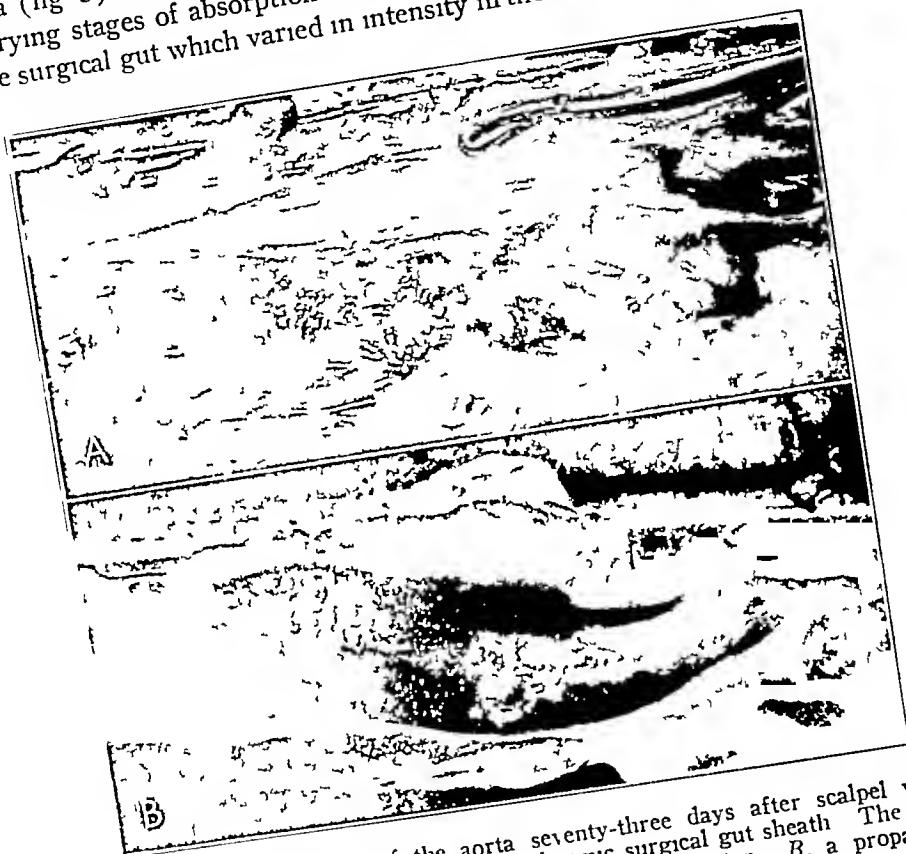


Fig 4—*A*, specimen of the aorta seventy-three days after scalpel wound and repair with gelatin sponge "cuff" and chromic suture; *B*, a propagating thrombus adherent to the wall of aorta where scalpel wound was produced forty days previously. Repair of wound by "cuff" and sheath. The thrombus did not exclude lumen completely.

The gelatin sponge was generally found to be in a more advanced stage of absorption than the surgical gut sheath. The chromic gut sheath of one manufacturer was somewhat less chromicized than that of a second manufacturer which prepared an especially heavily chromicized sheath. The rate and mode of absorption in the tissues of these two types of chromicized material were practically the same as those described in studies on the absorption of surgical gut, i.e., intermediate absorption



Fig. 5.—A photomicrograph of a healed wound in the wall of the aorta after twenty-four days. The fibrous scar has filled in the defect in the media and adventitia and has been covered by an endothelial surface which merges with the intima. Beneath the wound there is evidence of gelatin sponge in a moderate stage of absorption and replacement by fibrous tissue. Under this can be seen remnants of the chromic catgut suture which is undergoing absorption principally by the action of macrophages.

and slow absorption¹⁴ It was our impression that the more heavily chromicized material produced less tissue reaction during the relatively longer period of absorption than the other material

COMMENT

A significant point in this work is that arterial hemorrhage of a magnitude which would cause rapid exsanguination and death within a few minutes in experimental animals can be controlled by an absorbable hemostatic agent without resorting to ligation or arterial suture Granted that the hemostatic agent used was not sufficiently strong to withstand alone the arterial pressure after several days in the tissues, nevertheless the principle of control of arterial hemorrhage by an absorbable spongy material is of importance Owing to the friability of the sponge, it was found necessary to give additional support by a sheath of chromic surgical gut to prevent blowouts during the healing of the arterial wound The force of the arterial blood pressure was obviously too great for the physical structure of the sponge A contributing factor was the cutting effect of the sutures on the sponge which was produced by the arterial pulsations This sometimes resulted in cutting the gelatin sponge into several segments It is possible that this cutting effect may be prevented by using a tougher and stronger spongy material However, the chromic surgical gut sheath appeared adequate to hold the sponge in place and give it sufficient support during the period of healing of the arterial wound The sheaths which were not chromicized became so soft after a few days in the tissues that they were found to be unsuitable for this type of work The chromic surgical gut sheath represents an innovation in absorbable materials which may find uses in other fields of surgery and deserves further study,

Smith has used the cuff technic in experimental arterial anastomoses in which only seven interrupted sutures were used to bring the ends of the artery into apposition His experiences with different types of cuffs such as jugular vein segments, rubber, fascia, muscle and oxidized cellulose were unsatisfactory, as thromboses developed When concentrated fibrinogen solution was used to prepare a mold about the site of the anastomosis producing a fibrin layer it was found that this would not withstand the arterial pressure

¹⁴ Jenkins, H P, and Hrdina, L S Absorption of Surgical Gut (Catgut) I The Decline in Tensile Strength in the Tissues, Arch Surg **44** 881 (May) 1942, II Pepsin Digestion Tests for the Evaluation of Duration of Tensile Strength in the Tissues, *ibid* **44** 984 (June) 1942 Jenkins, H P, Hrdina, L S, Owens, F M, Jr, and Swisher, F M III Duration in the Tissues after Loss of Tensile Strength, *ibid* **45** 74 (July) 1942 Jenkins, H P IV Recommendations for Absorbability and Digestibility Specifications *ibid* **45** 323 (Aug) 1942

The blowout which occurred from the eroding effect of the chromic surgical gut sheath where it was held by the most proximal suture is of interest and demonstrates a potential hazard of this method. Murray¹⁵ has found that "rigid bands applied around the site of repair of vessels may be a menace in causing necrosis of the vessel wall." The chromic sheath usually becomes softened in the tissues after one or two weeks and should not present the same menace as a metal band. Nevertheless, this observation is significant and must be considered as a limitation to the method described, and illustrates the need for care in tying the sutures with just enough tension to make snug apposition of the sheath about the sponge without producing constriction of the vessel. Furthermore, it suggests that it would be wise to allow an excess of gelatin sponge to extend beyond the sheath to act as a buffering pad and thus protect the artery from erosion at the proximal end of the sheath. This would probably be desirable also at the distal end of the sheath.

There is no question about the desirability of utilizing a careful arterial suture for repair of wounds or for arterial anastomoses. The cuff technic such as was utilized in these animals merely offers an experimental method which might have some clinical application in circumstances in which a satisfactory repair is not feasible by the standard suture technic. It is probable that its most potential field of usefulness would be as an additional safeguard against blowout of an arterial suture line. There is no place in surgery where greater care must be exercised in placing every single suture and obtaining the optimum apposition with the minimum of strangulation of tissue. The outcome is so dependent on getting every suture correctly placed that only perfection in technic permits success in this type of surgery.

In traumatic lacerations of arteries, Pratt¹⁶ has found it desirable to reinforce the silk suture line with a strip of fascia or muscle wrapped about the site of repair. This suggests a need for some type of reinforcement which could be supplied by the method described here.

In arteriotomy for removal of an embolus, one may encounter some technical difficulty in obtaining a satisfactory closure with sutures if there is much arteriosclerotic change. Furthermore the healing of the vessel may be impaired by the presence of arteriosclerosis. The gelatin sponge cuff and chromic surgical gut sheath may be found to be especially appropriate under such circumstances as a reinforcement of the suture line is suggested by de Takats.¹⁷

¹⁵ Murray G. The Healing of Arteries and the Relationship to Secondary Hemorrhage. *Surgery* 18:124, 1945.

¹⁶ Pratt, G. H. The Surgical Management of Acute Arterial Occlusion. *JAMA* 130:827 (March 31) 1941.

¹⁷ de Takats, G. Personal Communication to Author.

It is possible that with the aid of the new absorbable hemostatic agents some modifications of the standard suture technic of vascular repair may be developed. In the repair of a wound of an artery or in an arterial anastomosis, the suture technic must perform two functions. It must bring the vessel walls into apposition and produce a "watertight" closure. It may be found feasible with these new hemostatic agents to depend on the sutures mainly for good apposition of the vessel wall and rely on the cuff of hemostatic agent to maintain a "watertight" repair of the wound or line of anastomosis. This may make it possible to obtain satisfactory arterial repair after a less careful suture technic than that now required.

One of the principal hazards of any type of blood vessel repair or anastomosis is the problem of thrombosis such as was observed in one experiment. In arterial suture, the development of a thrombus may be a relatively slow process which may require several weeks or more before the thrombus occludes the vessel. Meanwhile collateral circulation has had an opportunity to develop, so that in the event of complete occlusion by the thrombus the danger of peripheral ischemia and gangrene is substantially lessened. However, with the advent of the anticoagulants for use in the treatment of thrombotic vascular disease another hazard of vascular surgery may be minimized, as pointed out by Murray.¹⁸ A refinement in the anticoagulant therapy which deserves mention is the use of heparin in the Pitkin menstruum, such as was employed by Loewe, Rosenblatt and Hirsch for venous thromboembolic disease.¹⁹

If the gelatin sponge cuff and chromic catgut sheath should prove of value in minimizing blowouts, and with the aid of anticoagulants to prevent thromboses, it should be possible for more well trained surgeons to include in their repertory the surgery of the vascular system, which has thus far been a highly specialized field in which only a few have become proficient.

SUMMARY

An experimental nonsuture method for repair of wounds of arteries has been presented which consists of wrapping a cuff of gelatin sponge about the wound in the vessel and supporting this with a sheath of chromic surgical gut. With this method it has been possible to control hemorrhage, restore the flow of blood and prevent for the most part subsequent blowouts.

¹⁸ Murray, G D W. Heparin in Surgical Treatment of Blood Vessels, *Arch Surg* **40** 307 (Feb) 1940

¹⁹ Loewe L, Rosenblatt, P, and Hirsch, E. Venous Thromboembolic Disease, *JAMA* **130** 386 (Feb 16) 1946

CONCLUSIONS

The gelatin sponge cuff and chromic surgical gut sheath offer a new experimental method which may be found on further study to have a clinical application such as in the emergency treatment of wounds of major arteries, where one may not be in a position to do a careful arterial suture, and as a "secondary line of defense" against blowouts where arterial suture has been performed for a wound of the vessel or for anastomosis.

The chromic surgical gut sheath is an innovation in absorbable materials which may find uses in other fields of surgery.

NOTE.—Subsequent observations on the heat-sterilized type of heavily chromicized sheath suggest that six months or more may be required before absorption occurs.

ORTHOPEDIC OPERATIVE PROCEDURES ALLOWING EARLY MOTION

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NEW YORK

TO ACHIEVE early motion is one of the main objectives in modern treatment of orthopedic problems. The method of simply immobilizing an injured member in plaster for a prolonged period is being replaced by various operative procedures which allow early motion and which are designed to accomplish the dual purpose of producing a satisfactory end result and at the same time preserving tone and function of the surrounding soft tissues.

SURGICAL PROCEDURES

The following examples of surgical procedures are submitted as designed to accomplish these ends. The illustrations and the cases referred to are taken from various series at the Presbyterian Hospital and the New York Orthopaedic Hospital in New York city.

Clavicle—Injuries causing ruptures of the conoid and trapezoid ligaments produce complete coracoclavicular and acromioclavicular separations, as shown in figure 1A. Various types of treatment have been proposed for this kind of injury, ranging from prolonged immobilization in plaster to repair of the coracoclavicular ligaments by use of fascia or other retention sutures. These required long periods of immobilization. It seems that by far the best results are achieved when a Kirschner wire is drilled across the acromion into the distal clavicle, as in figure 1B. Usually the ruptured ligaments then heal spontaneously, and not infrequently calcification can be seen in the conoid and trapezoid ligaments, indicating a healing of this area of injury. The shoulder and arm are permitted to be used, no plaster is applied and no immobilization required. Thus, complete motion and maintenance of muscular tone are accomplished.

Elbow—In fractures of the radial head in which there is displacement into the brachialis anticus muscle (fig. 2A) immediate operation is indicated. An incision on the anterior aspect of the elbow should be

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made to evacuate the hematoma. This is a most important step in the prevention of myositis ossificans. The radial head is removed, as shown in figure 2B. Postoperatively, the elbow is put in a sling, and motion within pain limits is permitted within the first twenty-four hours. The patient should never receive massage or manipulation of the involved area. Prior to the use of this procedure, myositis ossificans developed in approximately 10 per cent of the cases, but since its adoption this most common complication has not developed in any case.



Fig. 1.—Injury of the clavicle. A, roentgenogram showing coracoclavicular and sternoclavicular separations; B, Kirschner wire drilled across the sternum into the distal clavicle.

Hard.—In cases of fractures of the metacarpal bones, shown in figure 3A, it has been found extremely advantageous to insert Kirschner wires both above and below the fracture, as indicated in figure 3B. This can be done under local anesthesia. The wires should be cut close to the bone and the skin allowed to close over the ends of the wire. Postoperatively no plaster is applied and early motion of the

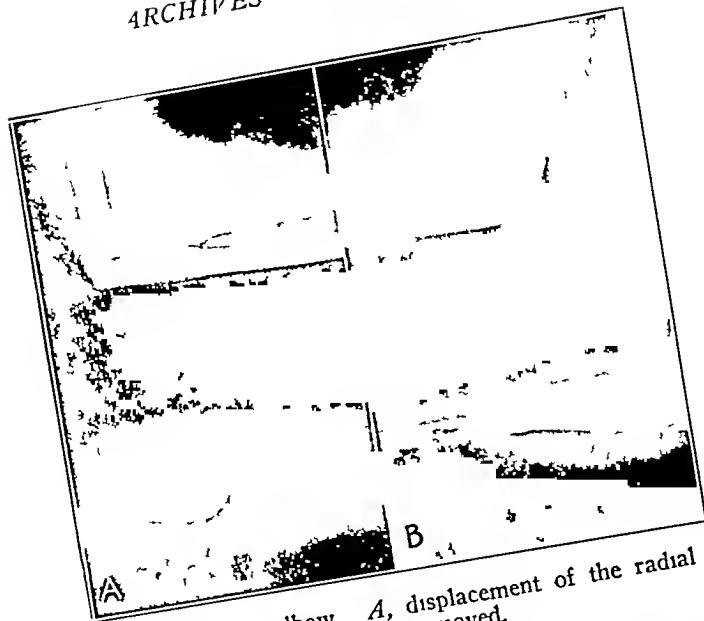


Fig. 2—Fracture of the elbow. A, displacement of the radial head into the brachialis anticus muscle. B, radial head removed.

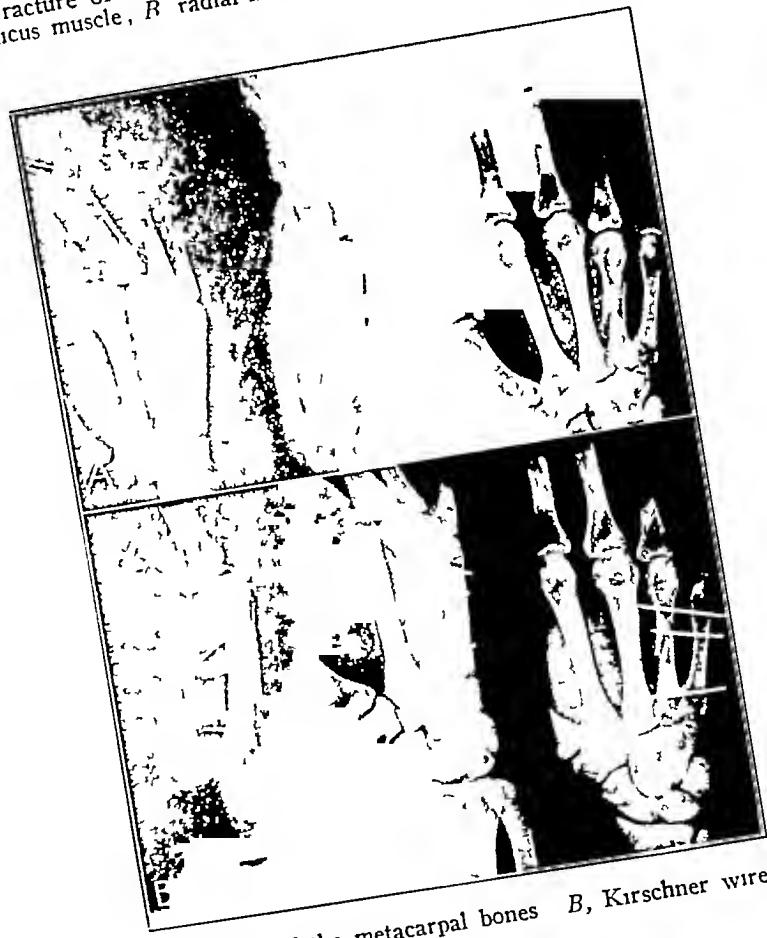


Fig. 3—4, fracture of the metacarpal bones B, Kirschner wires

hand is encouraged. The patient is generally allowed to resume his duties immediately. The wires are usually removed two months post-operatively. The roentgenograms show a fracture suffered by a neurosurgeon, who resumed operating thirty-six hours after injury. This method of immobilization and active use is applicable in fractures of all the metacarpal bones except the first.

Hip.—One of the most difficult problems to treat properly is that of the elderly patient who suffers an intertrochanteric fracture. Although



Fig. 4.—Reduction and immobilization of an intertrochanteric fracture of the hip.

it is known that these fractures heal rapidly and exceptionally well, it is difficult to immobilize them sufficiently to allow the patient to be ambulatory and thus prevent the common complications of decubiti or pulmonary stasis. It therefore is advantageous to insert a Smith-Petersen nail and then apply a McLaughlin plate, which is so fashioned that one can adjust for valgus or varus of the hip. In this way firm immobilization is accomplished, which permits the patient to be out of bed the following day. Thus at no time is it necessary to put the

patient in traction, suspension or plaster. It is felt that this method of fixation is advantageous in that it is adjustable for varus and valgus deformities. Previous to the use of this procedure intertrochanteric fractures presented much more of a problem than the transcervical fractures of the neck of the femur because of the difficulty in acquiring satisfactory immobilization without the use of plaster. Figure 4 shows the reduction and immobilization of such a fracture by this method.



Fig. 5.—Roentgenogram taken six weeks after the insertion of the Kunschner nail for a fracture of the femoral shaft.

Femur.—Recently the method used in treating fractures of the femoral shaft is the one popularized by the Germans during the last war. The use of a Kunschner nail inserted through the greater trochanter, down the medullary cavity and across the fracture line and well embedded into the distal fragment has given satisfactory immobilization and allowed early ambulation. Figure 5 is a roentgenogram of such a fracture made

six weeks after the insertion of the Kunschner nail. The patient was permitted to walk with crutches two weeks after operation. The crutches were discarded seven months postoperatively, at which time solid union of the bone was present.

Tibia.—It is well known that union is slow in fractures of the tibia, and often in the accomplishment of union considerable stiffening of the joints above and below the fracture is encountered. Therefore, early internal fixation by plate and screws and the use of a transfixion screw are often indicated. Figure 6 shows the postoperative roentgeno-



Fig. 6.—Postoperative roentgenogram of a fractured tibia treated with internal fixation by plate and screws.

gram of a fractured tibia treated in this manner. The extremity is then suspended in a Thomas splint and a Pierson attachment, and at no time is plaster applied. The joints of the knee and ankle are mobilized immediately, and the patient is allowed to be ambulatory as soon as the sutures are removed.

Ankle.—It is well known that one of the most difficult injuries to treat is a fracture of the ankle which extends into the joint, with a

separation of the inferior tibiofibular ligamentous structure (fig '7 A). The end result is rarely good unless the fractures are accurately reduced and firmly immobilized as in figure 7 B. Open reductions accomplish these two necessary objectives.



Fig 7.—Roentgenogram of a fractured ankle *A*, separation of the inferior tibiofibular ligamentous structure, *B*, reduction and immobilization.

Early motion is instituted, and plaster is never applied. By this method motion of the joints is maintained, soft parts do not become brawny and indurated and normal bony contour is restored.

Achilles Tendon.—In treatment of ruptures of the achilles tendon the method advocated by McLaughlin has been employed, which utilizes the principle of the Bunnell pull-out suture whereby the tendon is allowed

to heal end to end without the tension on the suture line produced by contraction of the gastrocnemius muscle. As illustrated in figure 8, the frayed ends of the Achilles tendon are freshened (*A, 1*). A drill hole is made from the lateral to the medial side of the os calcis (*A, 2*) and a stab wound made on the medial aspect of the os calcis (*A, 3*). A wire tension suture is then placed through the proximal end of the severed Achilles tendon. Through the hole in the os calcis a stainless steel bolt is passed (fig. 8 *B, 3*). The wire previously placed through the proximal portion of the tendon is then tightened around the bolt (*B, 2 and 3*). The approximated ends of the tendon are then sutured with black silk. This permits easy identification and withdrawal of the wire at a later date. The protruding end of the bolt is then cut flush with the os calcis and the entire area closed. In this manner there are no protruding bolts or wires through the skin.

After operation, the lower part of the leg is encased in an Unna paste boot and a three-quarter inch (2 cm) raise of heel given. The patient

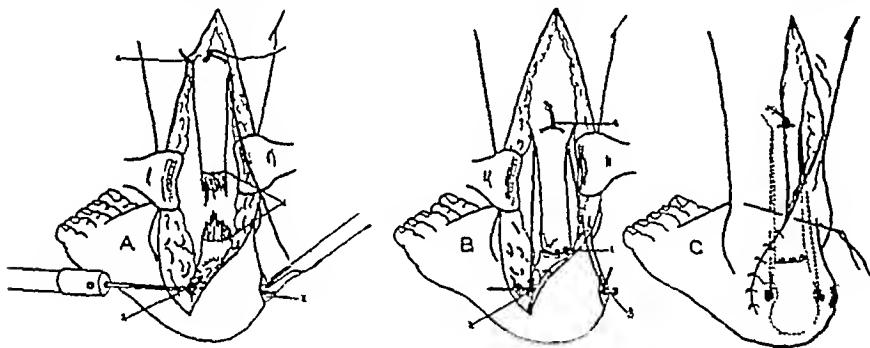


Fig. 8.—Treatment of rupture of the Achilles tendon

is allowed to walk about two weeks after operation. The wire and bolt are removed between three and six weeks postoperatively. This same principle is used in ruptures of the patellar tendon.

Spine.—The time-honored method of spine fusion—that of immobilization in plaster for six to twelve weeks—has undergone revolutionary changes within the past two years. The Hibbs type of fusion is performed in the regular manner, but in addition, according to the method advocated by Von Lackum, a bone chip is inserted into the facet space and a hole drilled from the lamina through the facet into the lateral mass of the sacrum. Into this hole a stainless steel screw is inserted (fig. 9). A one and a quarter inch (3 cm) screw is used in fusions of the fifth lumbar and first sacral vertebrae and a 1 inch (2.5 cm) screw in joints above this level. The fusion is usually reenforced by bone from the wing of the ilium. At times, however, bank bone is used, which is

bone of a homogenous nature that has been preserved by freezing and stored for use when required.

In fusions of the fifth lumbar and first sacral vertebrae the patient is out of bed on the twelfth postoperative day and allowed home wearing a Knight spinal brace on the fifteenth to twentieth postoperative day. In fusions of the fourth and fifth lumbar and first sacral vertebrae the patient is kept in bed for six weeks and then allowed to be ambulatory, again with the use of a Knight spinal brace.

It might be felt that too much operative work is advocated in this paper. However, I would like to point out that isolated instances have been chosen for the material on which this report is based. Also, it is of interest to know that at the Presbyterian and New York Orthopaedic hospitals open reduction is carried out in only 10 per cent of



Fig. 9.—Spine fusion in which screws have been used.

all the fractures treated. It is true that in most other hospitals open reduction is performed in only 3 per cent, but nonetheless it is felt that the handling of such fractures as are mentioned herein in the manner described affords the best results.

DISCUSSION

DR GEORGE J. CURRY, Flint, Mich.—I should like to discuss the paper of Dr Stinchfield. I strongly support the basic principles which he has emphasized for the management of certain fractures, urging the selection of any type of management that will permit early ambulation. The six examples that he has presented are well chosen and clearly show the value of early internal fixation.

I should like to comment especially on fractures in and about the hip joint. He made the statement that with the selection of internal fixation the patient with a fractured hip may become ambulatory early and be permitted sometimes to sit up the first hour or the first day. This is more applicable to fractures of the

femoral neck and certain fractures in the trochanteric area. During the past nine years at Hurley Hospital, Flint, Mich., we have operated for and internally fixed fractures in the hip region in 284 cases. My personal experience with intertrochanteric fractures of various types includes 89 cases in which internal fixation was carried out.

Roentgenograms frequently do not show the degree of comminution found at the time of operation. I feel that a note of caution should be given concerning cases with much comminution in relation to permitting ambulation in a wheel chair from the first postoperative day. It is obvious that the operation may be disturbed by the mechanical procedures necessary to accomplish this act. Considerable ambulation can be accomplished with the patient in bed by the use of the back rest and the frequent movement of unaffected extremities. I have seen patients who I thought were physiologically inert sitting in a wheel chair. Certainly the patient weighing 225 pounds who has an intertrochanteric fracture that has been internally fixed is a more difficult problem than the slender, smaller type. Patients with simple intertrochanteric fractures without comminution may enjoy all the phases of early ambulation.

There are intertrochanteric fractures of the complex type in which the comminution is so marked that one would not select any type of internal fixation because of the failure to find an area in which the internal fixation agent would hold. I believe that this type of fracture should have skeletal traction.

DR. PAUL GREELEY, Chicago. One thing I should like to ask Dr. Stinchfield is about the use of banked bone. There is a large group who believe that the use of such bone grafts is open to question because of absorption. I should like to know what the ultimate clinical and microscopic results are.

DR. FRANK E. STINCHFIELD. The question of "bone bank" is one of extreme interest to me. The bone bank was first established about a year ago at New York Orthopaedic Hospital for the purpose of supplying extra bone when needed in various surgical procedures. It is most appreciated in spine fusions, arthrodeses and scolioses.

The use of autogenous bone seems to be more satisfactory than the use of homogenous bone. I do not advocate the use of homogenous bone in place of autogenous bone but do advocate its use when autogenous bone is not available.

Actually, few of the bone cells survive. However, we have seen some of the cancellous bone cells survive but few, if any, of the cortical cells. The chief advantage of bank bone is that the bone affords a local source of calcium and acts as a trellis for new bone formation.

INTEROSSEOUS WIRING IN THE TREATMENT OF FRACTURES OF THE MANDIBLE

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INTEROSSEOUS wiring as a method of treatment in suitable fractures of the mandible has not been used as extensively as, in my opinion, its value justifies. Its use in the past has indeed been discouraged because of the complications that may follow. It is proposed to discuss, in this communication, the use of the method in the treatment of forty-eight fractures in 46 patients. Eighteen of these patients were soldiers injured by enemy action.

Wire suture of the fractured mandible is applicable in fractures of the edentulous mandible, fractures having an edentulous posterior frag-

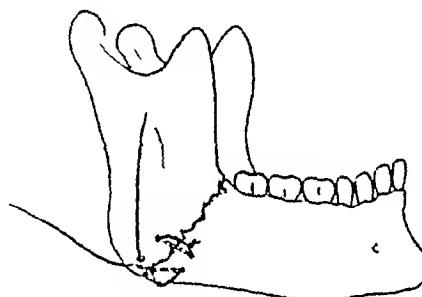


Fig. 1.—The method of fixation is shown, i.e., simple suture above and figure 8 suture below.

ment, multiple fractures (for stabilization of the main fracture), bilateral fracture through the mental foramina with downward displacement of the central fragment, gun (or shell) wounds (for stabilization when a portion is missing) and in fractures at the base of the condyle with displacement.

Incision is made below the mandibular line. No attempt is made to protect the infranondibular branch of the facial nerve, as recovery

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb 21, 1947

From the Division of Plastic Surgery, Toronto General Hospital, and the Division of Plastic Surgery, Christie Street Hospital, Department of Veterans' Affairs, Toronto. The illustrations are from the Medical Arts Department, Christie Street Hospital.

uniformly has followed its injury. The fracture ends are freed of soft tissue on both surfaces for about $\frac{3}{4}$ inch (19 cm). Two holes are drilled in each end as in figure 1. A high speed drill should not be used. Twenty-six gage stainless steel wire is threaded through the upper two holes as a simple suture. It is not tightened until the other wire is in

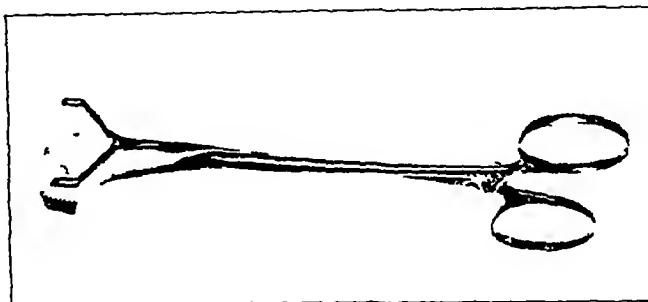


Fig 2.—A special instrument for holding the reduced fracture in position is illustrated. The pan is placed on the lingual side. Injury to deeper structures while drilling is prevented, and threading the wire through the drill holes is made easier. It was made for me by Messrs Chas F Thackray Ltd, 252 Regent Street, London W1, England.



Fig 3.—A fracture in the molar region is demonstrated. Displacement is typical. Extrusion of the second molar is present. Position following extraction of the molar, reduction of the fracture and fixation by interosseous wiring is shown at the right.

place. It was found that some degree of displacement of the posterior fragment recurred if the lower wire was also used as a simple suture. At the suggestion of Lieut Colonel G Franklin, C D C, this wire was

placed as a figure 8, with the crossed portion under the edge of the fragment not tending to become displaced. This prevented any shift postoperatively and has become a routine practice. The wires are tightened with the fracture reduced.

Sulfanilamide or sulfathiazole powder was dusted into the wound in 25 patients. Penicillin was given postoperatively to 24 patients. Closure was done in layers without drainage.

As it is believed that the least possible movement at a fracture line, particularly when foreign material is present, aids the development of

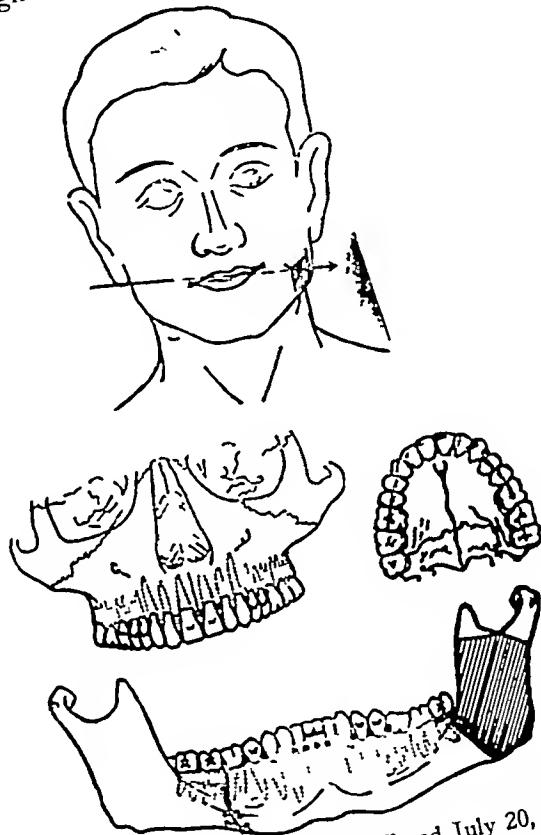


Fig 4.—The result of a gunshot wound suffered July 20, 1944 is indicated. The left ascending ramus was missing. Operation was done July 25. Interosseous wiring plus intraoral wiring was used to maintain the position of the central fragment.

solid union with a minimum of complication, intraoral fixation was used as well in 43 patients, pins and a Gunning splint in 1 patient each, and no secondary fixation was used in the forty-sixth patient. While not necessary, the instrument illustrated in figure 2 is of value in placing the holes and the wire. The fracture is reduced. The pan is placed on the lingual side of the fracture, the two arms on the buccal. Locking

the handles holds the fracture in position, allows the holes to be drilled without fear of injury to deeper structures and, since the floor of the pan slopes away from the mandible from above down, the wire ends present in the wound after passing through the drill holes

If a tooth in the line of fracture was rather loose or fractured, or had a denuded root in the fracture line, it was extracted before the incision was made. If possible, an intraoral dental roentgenogram should be taken, since the information obtained from it is of more value than that obtained from the ordinary large roentgenogram. Extraction was done in 17 instances. In 10 of these 17 cases a postoperative complication developed, an infection in 9 cases and delayed union in 1.

TABLE 1—Number of Patients and Fractures and Types of Fractures

Number of patients	46
Number of fractures	48
Number of angle fractures	21
Number of body fractures	7
Number of condyle fractures	2
Number of war injuries	18

TABLE 2—Complications

Osteomyelitis	1
Infection of soft tissue	
Severe	1
Mild	8
Delayed union	4
Nonunion	3
Sinus due to wire	2

The method has been used in 13 cases having an edentulous posterior fragment, in 12 of these the fracture was at the angle, and in 1 it was in the mental region. No fractures in edentulous patients are included in this study. Thirteen patients had multiple mandibular fractures, in 7 of these an angle fracture was wired, in 5 a fracture at or just back of the mental foramen was wired, and in 1 both angle fractures were wired. One instance of bilateral wiring in a case of fracture through the mental foramina is included in the series. As already stated, 18 cases were the result of war injury, the fractures being compound and either comminuted or multiple. In 2 cases condylar fractures with displacement were wired.

Six of the forty-eight fractures were simple. Postoperative infection did not develop in any of these. There were ten postoperative infections in the remaining forty-two compound fractures wired. Two of these were serious, in one case resulting in osteomyelitis with sequestration, and in nonunion in the other. One of the other eight infections produced

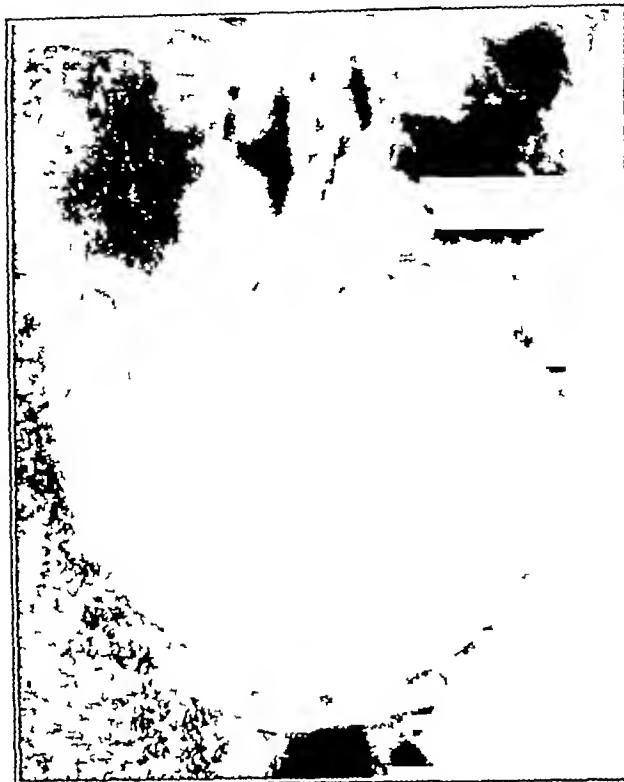


Fig 5.—The position of the wires in the patient referred to in figure 4 is shown as of December 1946. The left ascending ramus has been replaced by bone graft.



Fig 6.—A compound fracture of the right ascending ramus is shown. Marked displacement of the lateral orbital rim can be seen. The patient was hit over the right malar bone by the bolt of a rifle after firing. Operation was done eight hours after injury. The postoperative picture, at the right, shows the position obtained

an abscess involving soft tissue only which had to be drained but caused no further damage. The remaining seven were minor infections of the soft tissue in or near the region of the fracture.

The wires were eventually removed in 5 cases. Two were in the cases of serious infection and two were removed because of a persistent sinus leading down to the wire which promptly healed after removal of the wire. One set of wires, present in the symphysis region, was removed months later at the time of doing a buccal inlay graft (original injury due to a machine gun bullet).

Nonunion occurred in 3 cases, 2 already mentioned and the third for no obvious reason.

There was 1 death in this series. The patient, a soldier, had multiple injuries and died of uremia on the eleventh day after injury. No complication was present at the site of operation.

Union occurred in the cases without infection in an average of forty-four days. In cases with infection union occurred in an average of fifty-four days. The patient in whom osteomyelitis developed should not

TABLE 3.—Results

Death	1
Solid union	44
Bone graft..	8

have been operated on, and today would not be so treated. He was treated five days after injury. His face was markedly swollen and his mouth dirty. A third molar had to be extracted prior to operation.

In the 2 cases of condylar fracture wiring was done in order to reduce the fracture and to maintain the position. This fracture is one of the rare fractures, if not the only fracture, in the body in which little or no attempt is made to regain anatomic alignment. One of the open reductions proved rather simple technically, the other very difficult. In both cases wiring was done through a submandibular incision. It was felt that the functional result obtained was no better than that resulting from the usual methods of treatment, so open reductions were abandoned. While it is true that the immediate result was no better, it is impossible to say what the comparable result was years later. A study of the late results of fractures of the mandibular condylar process is an important contribution that has not as yet, to my knowledge, been made.

Four cases of delayed union and 3 of nonunion occurred in this series. All 3 nonunions were successfully treated by bone grafting, cancellous chips being used. Thus, of the forty-eight fractures treated, forty-four united satisfactorily.

The use of interosseous wiring in the treatment of fractures of the mandible is of value in maintaining edentulous fragments in anatomic position, in stabilizing a mandible when a portion is missing or when multiple fractures are present, in maintaining accurate reduction of the central fragment when fractures are present in both mental regions,

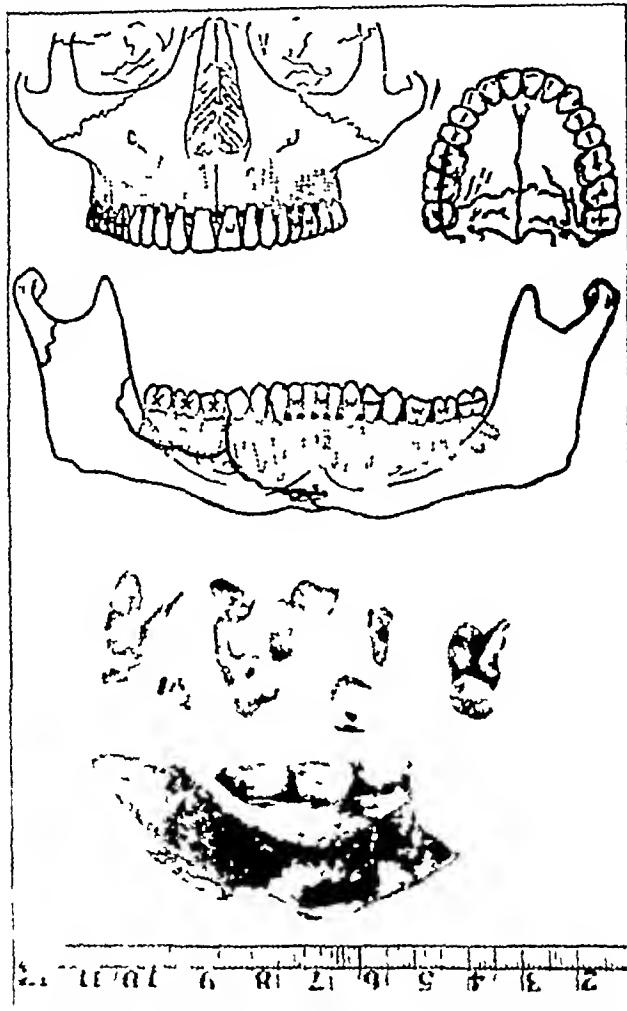


Fig 7.—The injury illustrated was suffered by a tank officer who was found unconscious lying part way out of the turret after night maneuvers just before D day. It was believed that he had been hit by a telephone guy wire. Interosseous wiring maintained the position of the right fragment. Operation was done six days after injury. The teeth and bone removed are shown.

and is of questionable value in the treatment of fractures of the condylar process. Interosseous wiring insures obtaining and maintaining a more accurate reduction of the fracture than any other applicable method of

therapy. The method should never be used when acute infection is present. Its use is not contraindicated in compound fractures free of clinical signs and symptoms of infection.

DISCUSSION

DR. PAUL GREELEY, Chicago I was pleased to listen to Dr Gordon's paper on open reduction of mandibular fractures. I fear, however, that some of our dental colleagues would consider this treatment heresy. I was glad that his position in the British Army was similar to that in the Navy in this country.

We are more pleased with the patients whom we treated with open operation than with those whom we treated conservatively. This also applies to fractures of the malar bone. The reason that treatment has been more successful in the last few years is that we are treating not only the fracture but the patient as a whole, with the aid of the various chemotherapeutic agents.

One thing which Dr Gordon mentioned was the late effect of no treatment of condylar fractures. I have not seen many late cases but patients who returned have come back with pain in the ear and pain in the ear when they chew, simulating the temporomandibular syndrome as described by Costen. This is relieved by resection of the condylar head.

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CHEMOTHERAPY IN GAS GANGRENE

An Experimental Study

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AND

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CINCINNATI

CONFLICTING evidence obtained from numerous clinical and experimental reports has resulted in considerable confusion regarding the value and limitations of chemotherapy in gas gangrene. Although penicillin has been generally recognized as being more effective than the sulfonamide compounds, opinion is still divided as to its real value. Fisher and his associates,¹ who had an opportunity to observe its influence on the incidence and course of gas gangrene in four hundred and thirty-six military wounds characterized by extensive laceration of muscle, compound fractures, arterial damage, gross contamination and many retained foreign bodies, concluded that the role of penicillin should be the prevention of gas gangrene rather than its treatment when already established. Jeffrey and Thomson² enthusiastically recommended the parenteral administration of penicillin at the time of primary débridement and for the following three to five days. Among 28 patients with true gas gangrene who were treated in this manner there were 7 deaths, giving a mortality of 25 per cent. These authors believed that the clinical response provided convincing evidence that penicillin can arrest the progressive myositis but that radical surgical intervention is still the main factor in treatment. On the other hand, Cutler and Sandusky³ concluded that penicillin used prophylactically in wounded and injured

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From the Department of Surgery of the University of Cincinnati College of Medicine and Cincinnati General Hospital. This paper is based in part on work done under grants from the National Institute of Health of the United States Public Health Service and the United States Army.

1 Fisher, G. H., Florey, M. E., Grimson, T. A., and Williams, P. H. Penicillin in Clostridial Infections, *Lancet* **1** 395, 1945.

2 Jeffrey, J. S., and Thomson, S. Penicillin in Battle Casualties, *Brit. M. J.* **1** 4, 1944.

3 Cutler, E. C., and Sandusky, W. R. Treatment of Clostridial Infections with Penicillin, *Brit. J. Surg.* **32** 168, 1945.

flying personnel did not prevent the development of gas gangrene and that the effect of this agent in modifying the infection could not be evaluated on the basis of the slight evidence at hand. They reported on 7 patients with gas gangrene treated both locally and parenterally with penicillin, 5 of whom had received this therapy immediately after primary débridement. Their data indicated that proper surgical débridement is the major factor in both the prophylaxis and the therapy of gas gangrene. The experience of Patterson, Keating and Clegg⁴ was similar in that the prophylactic use of penicillin in 8 cases failed to prevent the development of this infection. Conway,⁵ who reported on 14 cases of gas gangrene among 4,040 casualties from the Philippine Islands, also concluded that penicillin is of no value in the prevention of gas gangrene. In the therapy of established gas gangrene, penicillin has been considered to be the most promising chemotherapeutic agent by numerous authors,⁶ but the evidence for this is not clear. Meleney⁶¹ pointed out that penicillin has been used with encouraging results but only when given in large doses of 50,000 or even 100,000 units every two or three hours. In the same manner the United States War Department^{6m} recommended 200,000 to 400,000 units per day for effective

4 Patterson, T. C., Keating, C., and Clegg, H. W. Experiences in the Prophylaxis and Treatment of Clostridial Infections in Casualties from the Invasion of Europe, *Brit. J. Surg.* **33**: 74, 1945.

5 Conway, H. Anaerobic Infection and Gangrene of War Wounds in Casualties of the Philippine Islands, *Surgery* **19**: 553, 1946.

6 (a) Altemeier, W. A. Penicillin in Surgery, *South. M. J.* **37**: 494, 1944.
(b) Harris, C. M., and Leviton, L. R. Penicillin Treatment of Gas Gangrene, *Am. J. Surg.* **69**: 391, 1945. (c) Herrell, W. E. Penicillin and Other Antibiotic Agents, Philadelphia, W. B. Saunders Company, 1945. (d) Jeffrey, J. S., and Thomson, S. Gas Gangrene in Italy. A Study of Thirty-Three Cases Treated with Penicillin, *Brit. J. Surg.* **32**: 159, 1944. (e) Keefer, C. S., and Anderson, D. G. Penicillin in the Treatment of Infections, New York, Oxford University Press, 1945. (f) Keppl, M. F., Ochsner, A., and Dixon, J. L. Two Cases of Clostridium Welchii Infection Treated with Penicillin, *J. A. M. A.* **126**: 96 (Sept. 9) 1944. (g) Kolmer, J. A. Penicillin Therapy, Including Tyrothricin and Other Antibiotic Therapy, New York, D. Appleton-Century Company, Inc., 1945. (h) Langley, F. H., and Winkelstein, L. B. Gas Gangrene. Study of Ninety-Six Cases Treated in Evacuation Hospital, *J. A. M. A.* **128**: 783 (July 14) 1945. (i) Lockwood, J. S., in Christopher, F. Textbook of Surgery, ed. 4, Philadelphia, W. B. Saunders Company, 1945. (j) MacLennan, J. D., and MacFarlane, M. G. Treatment of Gas Gangrene, *Brit. M. J.* **1**: 683, 1944. (k) McKnight, W. B., Loewenberg, R. D., and Wright, V. L. Penicillin in Gas Gangrene. Report of Successfully Treated Case, *J. A. M. A.* **124**: 360 (Feb. 5) 1944. (l) Meleney, F. L., in Christopher, F. Textbook of Surgery, ed. 4, Philadelphia, W. B. Saunders Company, 1945. (m) Notes on Care of Battle Casualties, United States War Department, Technical Bulletin (TB Med 147), Washington, D. C., Government Printing Office, March 1945. Jeffrey and Thomson.²

therapy. On the other hand, Odom⁷ felt that penicillin's sole value lay in the control of associated secondary infection, and Conway⁸ believed that it was of no value in the therapy of established gas gangrene in casualties from the Philippine Islands.

Experimental studies have not eliminated the confusion. In 1942 and 1943 McIntosh and Selbie⁹ found penicillin to be effective in experimental infections produced by the intramuscular injection of 0.1 cc of a 5 per cent solution of calcium chloride and 0.1 cc of a washed suspension of *Clostridium welchii* prepared from eighteen hour cultures. The local injection of 34 units of penicillin in 24 mice at the time of the bacterial inoculation was followed by survival of 100 per cent of the animals. When therapy was delayed for two hours there was a survival of 92 per cent but when it was delayed for three hours there was a survival of only 17 per cent. Similar observations were reported by Hac and Hubert¹⁰ on experimental gas gangrene in mice produced by the intramuscular inoculation of an unwashed eighteen hour culture of *C. welchii*. Subcutaneous injections of penicillin in doses of 5 and 500 Oxford units given immediately reduced the mortality from 90 per cent in the controls to 46 per cent and 2 per cent respectively. Experiments carried out on a small number of guinea pigs supported the observations made in the mice.

Likewise Siebenmann and Plummer¹¹ found that the local injection of 50 units of penicillin was effective in mice one hour after infection produced by the intramuscular injection of a suspension of *C. welchii* in a 50 per cent solution of calcium chloride but ineffective when the same dose was given in the opposite leg. However, when the dose in the uninjected leg was increased fivefold to 250 units, it became nearly as effective as the 50 units injected locally at the site of infection. A single intravenous injection of penicillin (250 units) was fairly effective when administered one hour after infection but ineffective when given as late as four hours after infection.

In the experiments of Dawson, Hobby, Meyer and Chaffee¹² with infections produced by intramuscular inoculations of guinea pigs with a 10 per cent solution of calcium chloride and toxin-free suspensions of

⁷ Odom C P. Causes of Amputation in Battle Casualties with Emphasis on Gastrointestinal Injury. *Surgery* 19: 562, 1946.

⁸ McIntosh J and Selbie F R. Combined Action of Antitoxin and Local Chemotherapy on *C. Welchi* Infection in Mice. *Lancet* 2: 224, 1943.

⁹ Hac I R and Hubert A C. Penicillin in the Treatment of Experimental *Clostridium Welchi* Infection. *Proc Soc Exper Biol & Med* 53: 61, 1943.

¹⁰ Siebenmann C O, and Plummer, E. Chemotherapy and Antitoxin Therapy in Experimental *C. Welchi* Infection in Mice. *J Pharmacol & Exper Therap* 83: 71, 1945.

¹¹ Dawson M H, Hobby, G L, Meyer, K, and Chaffee, E. Penicillin as a Therapeutic Agent, *Ann Int Med* 19: 707, 1943.

Clostridium welchii, the injection of 666 units of penicillin subcutaneously protected all the animals receiving 0.1 cc of a suspension of *Clostridium welchii* spores (one to two minimum lethal doses) but none of those receiving 0.2 cc.

Dowdy, Sewell and Vincent¹² concluded in 1944 that penicillin was an effective agent in prophylaxis of experimental gas gangrene in dogs produced by the standardized injection of a mixture of various clostridia and the *Staphylococcus aureus* which was adjusted to produce death in a high percentage of the controls but not an overwhelming infection.

No report of the use of streptomycin in established infections produced by *Clostridium welchii* has been found. Robinson, Smith and Graessle¹³ found that the sensitivity of *Clostridium welchii* to streptomycin in vitro was not considerable, a concentration of greater than 104 units per cubic centimeter being required for inhibition of growth. DeBakey and Pulaski¹⁴ have reported the effect of streptomycin on infected wounds, one third of which were contaminated by *Clostridium welchii*, but not in cases of clinical gas gangrene.

In all the animal experiments which have been summarized the infections were produced by the inoculation of bacterial cultures through hypodermic needles into healthy muscle, although in some instances calcium chloride was used as a local irritant. Infections produced under such conditions are different from those seen clinically, in which masses of devitalized and degenerated tissue are prominent characteristics. In our opinion, this difference is largely responsible for the discrepancy between the obvious effectiveness of penicillin in gas gangrene experimentally produced and its questionable value in the type occurring clinically. A method has therefore been devised of measuring accurately the value and limitations of chemotherapy in standardized experimental gas gangrene which is produced in the presence of crushed muscle and dirt and which simulates closely the conditions of the clinical type.

MATERIAL

Guinea pigs weighing 350 to 450 Gm were chosen as the experimental animals because of their pronounced susceptibility to infection with *Clostridium welchii* which resembles that of human beings. *Clostridium welchii* was chosen as the test organism because of its occurrence alone or in

12 Dowdy, A. H., Sewell, R. L., and Vincent, J. G. The Prophylaxis and Therapeusis of Clostridial Infections (Gas Gangrene), New York State J Med 44: 1890, 1944.

13 Robinson, H. J., Smith, D. G., and Graessle, O. E. Chemotherapeutic Properties of Streptomycin, Proc Soc Exper Biol & Med 57: 226, 1944.

14 DeBakey, M., and Pulaski, E. J. An Analysis of the Experience with Streptomycin Therapy in United States Army Hospitals, Surgery 20: 749, 1946.

association with other bacteria in 56 to 100 per cent of a series of reported cases of gas gangrene.¹⁵ The virulence of many strains of *Clostridium welchii* obtained from a variety of sources including soil, clothing and contaminated or infected wounds was investigated by determining the minimal lethal dose for these animals. For most of the strains tested the virulence was either relatively low or extremely variable. A strain of high virulence known as BP6K was obtained from Dr Milan Logan, of the department of biochemistry, but preliminary studies showed that the minimum lethal dose of this strain also fluctuated widely. Cultures which were grown in the pancreatic digest mediums developed by Logan showed prolific growth, with much turbidity and formation of gas, and were much more virulent than those grown in deep meat broth, brain broth or other mediums. When incubated for only four and one-half to six hours in the pancreatic digest mediums, they produced death in much higher dilutions than when incubated for eighteen to twenty-four hours. In addition it was found that weekly passage through pigeons was necessary to maintain the virulence at a high level, and this was routinely done by Dr Logan and Dr Tytell. It was therefore possible to standardize the virulence of a strain of *Clostridium welchii* at a high level by incubating for four and a half to five and a half hours in pancreatic digest medium a culture of BP6K passed weekly through a pigeon.

The penicillin used was the commercial sodium salt presently available, and the streptomycin used was in the hydrochloride form. Each was prepared in solution with sterile isotonic solution of sodium chloride.

METHOD

The infection was produced by the inoculation of measured quantities of bacteria in closed wounds containing crushed muscle and sterilized dirt by the following method. The skin over the lower part of the back and the posterior lateral aspects of the thigh of a guinea pig was prepared by being shaved and scrubbed with soap and water for five minutes. After the induction of drop ether anesthesia, the preparation of the operative area was completed by the application of alcohol, ether and tincture of iodine. A sterile drape containing a hole 15 by 10 cm was then applied to the prepared area. It was necessary to take these steps to eliminate or minimize the introduction of *Clostridium welchii* spores normally resident on the skin or hair of the guinea pig.¹⁶ Under aseptic precautions, with the use of gowns, gloves, cap and mask, an incision 10 cm in length was made through the skin and subcutaneous tissues over the midportion of the posterolateral aspect of the right thigh and developed down to and beyond the femur. The muscles on each side of the wound were then crushed five times with a Kocher clamp and avulsed by twisting the clamp at an angle of 180 degrees. Into each wound 0.5 cc (0.6 Gm.) of an autoclaved and finely divided mixture of soil and cinders was placed. The

¹⁵ Altemeier, W. A., and Furste, W. L. Gas Gangrene. A Collective Review of the Literature, Surg., Gynec. & Obst., to be published.

¹⁶ Altemeier, W. A. The Rapid Identification of the *Clostridium Welchii* in Accidental Wounds, Surg., Gynec. & Obst. 78: 411, 1944.

edges of the wound were then closed with interrupted fine black silk sutures to minimize leakage of the inoculum and subsequent secondary contamination. In a previous series of experiments¹⁵ it had been determined that the presence of crushed muscle and dirt increased the virulence of *C. welchii* one million times. Serial dilutions of a four and a half to six hour culture of *C. welchii* were then made to the tenth power, sterile pancreatic digest medium being used as the diluent since this gave more uniform results than isotonic solution of sodium chloride. Finally 0.5 cc. of one of the higher dilutions, representing one or multiples of one minimum lethal dose, was injected through the skin into the area of crushed muscle and dirt through a 25 gage needle and a tuberculin syringe. The minimum lethal dose was considered to be 0.5 cc. of the highest dilution of a culture on a given day which killed within four and two-thirds days all the guinea pigs under the conditions of the experiment. In addition 0.5 cc. of all lower dilutions had to kill the animal within the same unit of time.

Six experiments, each involving 69 to 75 guinea pigs, were carried out, four with penicillin and two with streptomycin. A total of 444 animals were used. After production of the standardized wounds in each experiment, the animals were divided into three groups of approximately 25 each, one group for controls used to establish a minimum lethal dose for that day under the conditions of the experiment, another for measurement of the chemotherapeutic agent's prophylactic value in a given dose and the third for determination of its therapeutic value. Penicillin or streptomycin was given intramuscularly every three hours for ninety-six hours after the operation, the first prophylactic dose being administered simultaneously with the inoculation of the bacteria into the wound containing crushed muscle and dirt and the first therapeutic injection being made six to eight hours after inoculation. In order to explore as fully as possible its value, the dose of penicillin was varied in the four experiments, 2,000, 8,000, 32,000 and 96,000 units per kilogram of weight being used every twenty-four hours. The dose of streptomycin was 44.44 and 136 mg per kilogram every twenty-four hours. In each instance the twenty-four hour dose was divided into eight equal parts and then administered intramuscularly every three hours, the two forelimbs and left hindlimb being used alternately. No further operative procedure or other form of treatment was used. The animals and their wounds were then carefully observed and the date of death recorded in each instance. In this manner it was possible to determine the minimum lethal dose for that day and to measure accurately the effectiveness of the two chemotherapeutic agents in a severe form of experimental gas gangrene closely similar to the clinical type. The minimum lethal dose varied between 0.5 cc. of a 10^{-8} dilution and 0.5 cc. of a 10^{-10} dilution in the various experiments.

RESULTS

Penicillin Prophylaxis—When a standard dose of 2,000 units of penicillin per kilogram of weight per day was used in animals inoculated with one to one thousand minimum lethal doses under the conditions described, no measurable effect was evident and all the animals died within two and two-thirds days at a slightly faster rate than the controls (figs 1 and 2). On a basis of units per kilogram, this dose is comparable to 15,000 to 20,000 units every three hours in an adult human being. When the dose was increased four times to 8,000 units per kilogram, a definite beneficial effect was detected, the rate of death

being retarded and 16 per cent of the animals surviving at the end of four and two-thirds days. In the group of animals receiving 32,000 units per kilogram or sixteen times the standard dose, the prophylactic value of penicillin became evident (fig 2). The size and spread of the lesion were greatly diminished and 64 per cent of the animals survived for the period of four and two-thirds days. An additional increase in the protective effect of penicillin was apparent when the dose was increased to 96,000 units per kilogram. The control of the rate of spread of the infection was obvious, the lesions being small and often insignificant compared with those in the controls. Ninety per cent of the animals

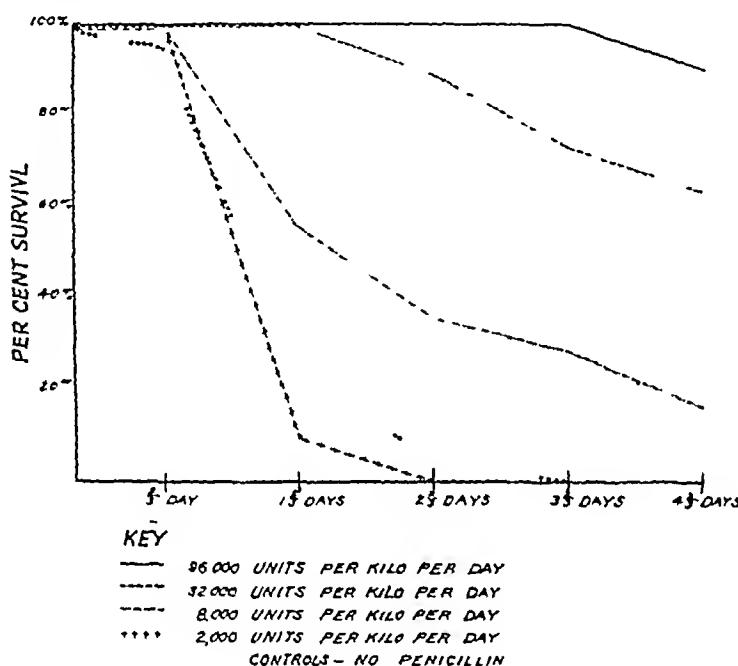


Fig. 1.—The progressive prophylactic effect of increasing doses of penicillin in gas gangrene produced experimentally in guinea pigs. Penicillin therapy was started immediately.

treated with this dose survived for four and two-thirds days even under the severe challenge of this type of infection.

Penicillin Therapy.—When the onset of penicillin therapy was delayed for six hours after challenge and when the infection was already established, the effectiveness of the drug was decreased. There was no significant difference between the appearance of the lesion or the survival rate in the control groups treated without penicillin and that in the groups receiving the standard dose of 2,000 units per kilogram, since all the animals died (fig 3). Doses of 8,000 and 32,000 units per kilogram produced some retardation in the spread of the infection.

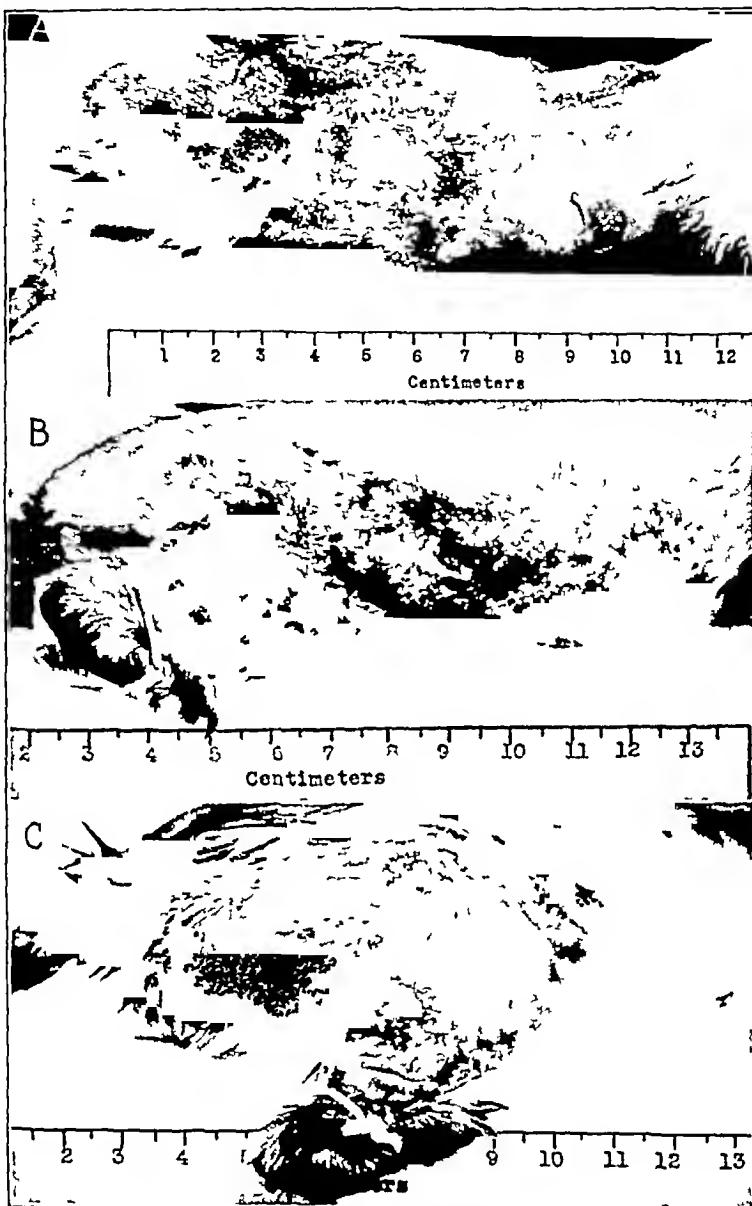


Fig 2.—*A*, typical appearance of the experimental gas gangrene developing in an untreated (control) animal receiving one minimum lethal dose of *Clostridium welchii*. Death occurred in thirty hours after challenge. *B*, the ineffectiveness of immediate penicillin therapy in standard doses for experimental infection produced by one minimum lethal dose (0.5 cc of 10^{-6} dilution) of *C. welchii* is clearly shown. A daily dose of 2,000 units of penicillin per kilogram was used in eight divided injections every three hours. *C*, showing the effectiveness of immediate penicillin treatment on experimental gas gangrene in an animal receiving one thousand minimum lethal doses of *C. welchii*. The infection has been obviously attenuated and kept localized by a daily dose of 32,000 units per kilogram in eight divided injections every three hours.

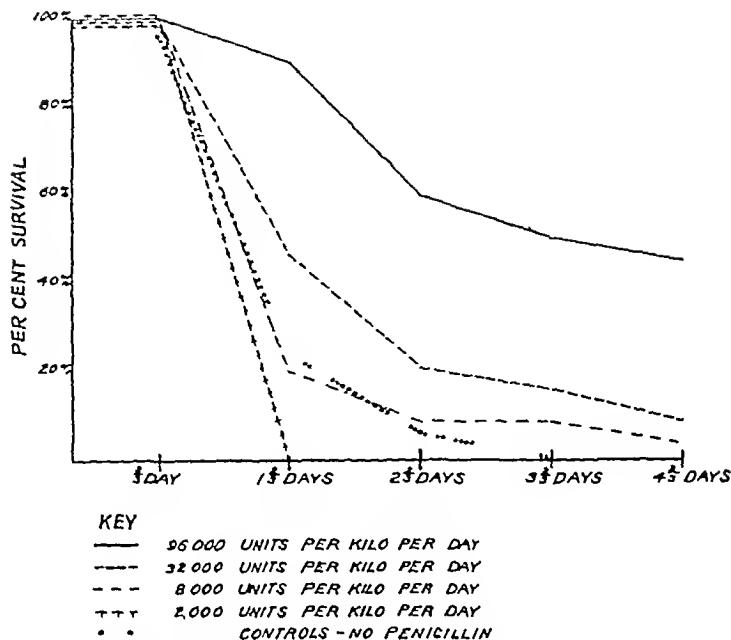


Fig. 3.—The definite and unquestionable beneficial therapeutic effect of massive doses of penicillin on the survival rate of animals challenged six hours before

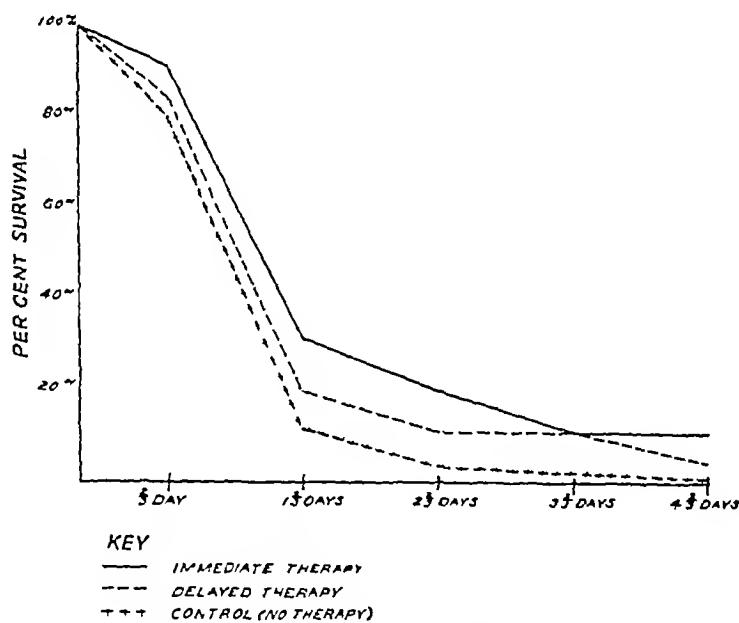


Fig. 4.—The prophylactic and therapeutic ineffectiveness of streptomycin in experimental gas gangrene when given in the moderately large dosage of 44.44 mg per kilogram per day

and in the rate of death, but less than 10 per cent of the animals survived for the four and two-thirds days. Massive doses of 96,000 units per kilogram produced an obvious effect on the course of the infection. The severity of the infection was diminished, as evidenced by the smaller size of the lesions, the better condition of the animals and the survival of 45 per cent of them during the four and two-thirds days.

When the period of observation was extended to fourteen days after challenge and ten days after cessation of penicillin therapy, all the animals died but 2.

Streptomycin Prophylaxis.—In the group of animals receiving 44.44 mg of streptomycin per kilogram every twenty-four hours divided

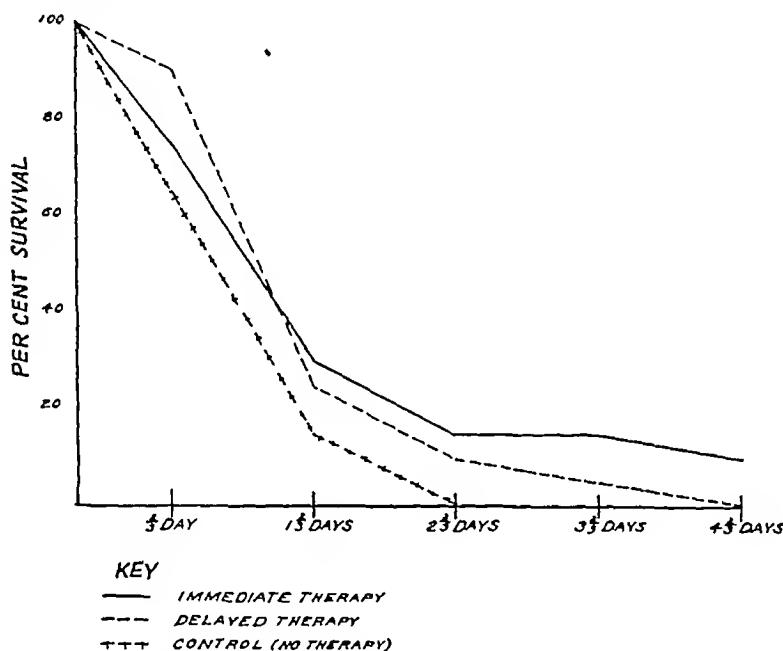


Fig 5.—Ineffectiveness of large doses, 136 mg per kilogram per day, of streptomycin in the prevention or treatment of experimental gas gangrene.

into doses given every three hours there was no significant difference in the severity of the infection or in the rate of death as compared with the occurrence in the control group receiving no treatment. Only 12.0 per cent of the treated animals survived for the four and two-thirds days. When the dose was increased to 136 mg per kilogram every twenty-four hours, the result was approximately the same (figs 4 and 5). Observations on the progress of the infection in the animals prior to their death showed no appreciable difference in the lesions of any group. All spread swiftly, with the production of discoloration, edema and gas in the tissues of the entire thigh, hip and, frequently, abdominal wall (fig 6).

Streptomycin Therapy.—When streptomycin therapy with either 444 mg or 136 mg per kilogram every twenty-four hours was delayed for six to eight hours after inoculation of one to ten thousand minimum lethal doses of *C. welchii*, the infection, already established, progressed thereafter practically uninhibited, the treated animals appearing to be just as sick as the controls and dying at approximately the same rate (figs 4 and 5).

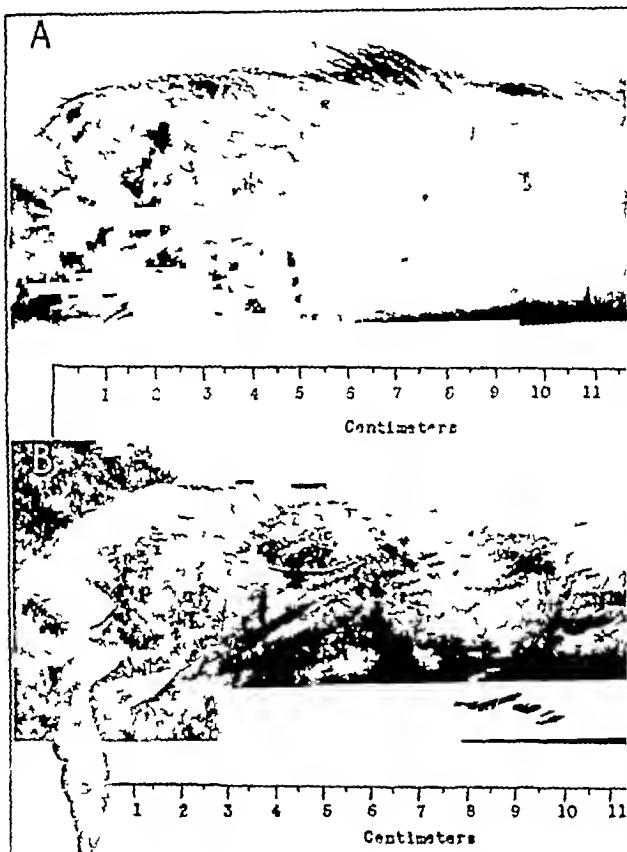


Fig. 6.—*A*, fulminating gas gangrene extending over abdominal wall in an animal receiving one hundred minimum lethal doses of *C. welchii* who was given intensive and immediate streptomycin therapy in daily amounts of 136 mg per kilogram divided into eight doses given every three hours. Death occurred in nineteen hours. *B*, extensive gas gangrene produced by ten minimum lethal doses which was unaffected by similar treatment with streptomycin started eight hours after bacterial challenge. Death occurred in thirty-five hours.

COMMENT

An analysis of these experimental studies explains many of the discrepancies in the results of chemotherapy in gas gangrene. It is obvious that the experimental infection produced in the presence of crushed muscle and dirt is considerably different from that produced by the

simple injection of bacteria with or without local irritants into healthy muscle. It is not only much more severe but also much more refractive to therapy. Consequently, chemotherapeutic agents have been made to appear much more effective in the past than they really are when tested against experimental infections produced by simple injection of bacteria. In the severer form of gas gangrene in animals penicillin has proved to be the chemotherapeutic agent of choice, while streptomycin was found to have little or no value. It is important to note that penicillin was much more effective when used prophylactically than when used in infections already established. This emphasizes the advisability of starting parenteral administration of penicillin as soon after injury as possible and before débridement. The longer chemotherapy is delayed, the more limited the response to it will be.

It is also significant that under the challenge of severe infection penicillin had little or no measurable value when used either prophylactically or therapeutically in average dosage. Only when the dose was increased sixteen times did its effect prophylactically become obvious, and only when it was increased forty-eight times did its therapeutic effect become unquestionable. This probably explains, at least in part, many of the differences in the clinical results which have been obtained with penicillin. It is realized that this experiment has put penicillin to a most severe test not only because the wounds in which the infection was produced contained crushed muscle and dirt but also because they were closed with sutures and were not treated subsequently by surgical incision or excision. This was done purposely to eliminate the confusing effect of any other therapeutic factor. It would seem that early and adequate surgical treatment should still be considered the most important factor in the prevention of clinical gas gangrene and that parenterally administered penicillin may be expected to be a valuable therapeutic adjunct.

As demonstrated in these studies, massive doses of penicillin checked the invasive qualities of the infection, both retarding its development and limiting its spread under adverse conditions. This fact suggests that the early clinical use of penicillin in large doses up to 1,000,000 units every three hours will probably have the following effects: (1) limitation of the invasive qualities of the infection and prolongation of the period during which effective surgical procedures short of amputation can be done, (2) the possibility of amputation at lower levels, resulting in less mutilating sequelae, when amputation is necessary in advanced infections, (3) inhibition not only of the secondary bacterial invaders usually susceptible to penicillin but also of many of the organisms ordinarily resistant to average doses, and (4) marked reduction in the mortality.

SUMMARY

The effect of penicillin and streptomycin has been carefully measured in a series of experimental studies on a severe and standardized form of gas gangrene in animals simulating the type which develops clinically in man. Although streptomycin was found to have no significant therapeutic value, penicillin was shown to have a notable beneficial effect on the rate of development and the extensiveness of the infection as well as on the mortality. Since the effect of chemotherapy was greatly modified by the time of onset and the size of the dose in these experiments, it would seem advisable to administer penicillin parenterally as soon as possible and in conjunction with surgical treatment in persons with gas gangrene or with wounds of the type which predisposes to its development and to continue using it thereafter both preoperatively and postoperatively in large doses up to 1,000,000 units every three hours until the threat of this infection is over.

OSTEOCHONDROSARCOMA OF THE STERNUM

Use of Tantalum Plate as a Prosthesis

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THE METAL tantalum has been shown to be inert and well tolerated by body tissues¹. It has been widely used for the repair of defects following wounds of the skull sustained in war in the form of tantalum plate.² The material is also available and used as tantalum foil and tantalum suture material³. In the case to be presented a large sheet of tantalum 0.0125 inch (0.032 cm) thick was used as a prosthesis after removal of the body of the sternum and a large part of the anterior thoracic wall for osteochondrosarcoma originating in the sternum. It was hoped that the tantalum plate might serve as a permanent prosthesis. However, the motion of the thoracic wall produced so much bleeding from the tissues surrounding the plate that formation of hematoma necessitated removal of the plate. The plate did, however, serve as a valuable temporary prosthesis to prevent paradoxical respiration and to tide the patient over the early postoperative period.

REPORT OF A CASE

K. F., a white farmer and laborer aged 41, was admitted to Norton Memorial Infirmary on Aug 24, 1946, with the history of a tumor on the anterior surface of the sternum. This tumor had been first noticed about eighteen months previously, at which time it was about one sixteenth of an inch (0.16 cm) thick and 2 inches (5 cm) in diameter. It was firm, fixed and painless but had grown progressively larger, until at the time of the patient's admission to the hospital it measured 4 by 6 inches (10 by 15 cm.) and projected 3 inches (7.6 cm) from the anterior surface of the sternum, lying in the midline and extending from the level of the third to the level of the sixth costal cartilage. With the exception of frequent attacks of dyspnea, the patient had no other complaints. His previous health had been excellent. He stated that in the course of his work he frequently held an

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1 Carney, H. M., and Burch, J. C. Proc. Soc. Exper. Biol. & Med. **51**, 147-148 (Oct.) 1942 Burke, G. L. Canad. M. A. J. **43** 125-128 (Aug.) 1940 Pudenz, R. H. Surgery **12** 791-797 (Nov.) 1942

2 Woodhall, B., and Spurling, R. G. Ann. Surg. **121** 649-671 (May) 1945

3 Olson, C. T. Indust. Med. **13** 917-920 (Nov.) 1944

anger or a brace and hit against his chest. General examination of the patient showed the physical condition to be essentially normal with the exception that the heart was shifted slightly to the left and the contour of the chest was deformed by the tumor (figs 1 and 2).

The roentgenologic report by Dr J C Bell was as follows:

Roentgenograms of the chest and the sternum were made with the patient in various positions. There is an extensive destructive lesion involving the middle third of the sternum. A tumor mass extends posteriorly into the thorax a distance of almost 2 inches (5 cm) and extends upward and downward a distance of almost 6 inches (15 cm). The same tumor mass extends far anteriorly to the level of the thoracic wall, where a large tumor mass of soft tissue can be seen, within



Fig 1.—Anterior view of thorax.

which are many areas of calcification. There is definite destruction in the cortex of the anterior part of the sternum. The changes here are due to the presence of a tumor presumably an osteochondroma, which in my opinion may very well have undergone a sarcomatous change. No evidence of destruction of the ribs is seen. No other abnormalities are noted (fig 3).

Operation.—On Aug 26, 1946, with the patient under anesthesia induced by endotracheally administered cyclopropane, oxygen and ether, the sternum and tumor were exposed through a "T" incision, the cross bar of the "T" being at the second costal cartilage and the vertical limb extending over the tumor down to the xiphoid. The skin flaps were reflected laterally away from the presenting

mass. The internal mammary vessels were exposed and ligated with silk in the second interspace on both sides. Subcutaneous bleeding was controlled by electrocoagulation. The third, fourth, fifth, sixth and seventh costal cartilages were divided 1 inch (2.5 cm) from the tumor on both sides. The sternum was divided at the junction of the body and the manubrium. The tumor and sternum were retracted ventrally and dissected away from the mediastinal structures. Both pleural spaces were opened. Respiration was maintained by intermittent positive



Fig. 2.—Lateral view of thorax.

pressure during the time that the chest was open. The lower end of the body of the sternum was detached at the xiphoid. Hemostasis was completed by silk ligatures and electrocoagulation.

The defect in the bony chest wall measured approximately 12.5 by 12.5 cm. At this time a tantalum plate was cut and fitted to the defect, overlapping the stumps of the costal cartilages, the manubrium and the xiphoid approximately 0.5 cm. Grooves were cut in the xiphoid, the manubrium and the stumps of the costal cartilages to allow the plate to be mortised into place under tension.